THE FIELDS AND METHODS OF KNOWLEDGE

RAYMOND F. PIPER — PAUL W. WARD

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(Frontispiece)

THE GREAT SPIRAL IN ANDROMEDA

This is one of the largest and nearest of a multitude of star systems which lie very far beyond the confines of the Milky Way. It is made up of immense swarms of stars among which our sun would be lost. Its extreme diameter is 45,500 light years. It takes 17,000,000 years for this spiral to turn once around. It is approaching the earth at the rate of 105 miles per second. Light from it requires nearly a million years to reach us. (Photographed by G. W. Ritchey with the 24-inch reflector of Yerkes Observatory, September 18, 1901; exposure four hours.)

THE FIELDS AND METHODS OF KNOWLEDGE

A TEXTBOOK IN ORIENTATION AND LOGIC

BY

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TO

OUR STUDENTS

PAST AND PRESENT

PREFACE

This book is a survey of the sciences and an analysis of scientific method. It is a result of experiments begun in 1922 in teaching a course in logic and orientation to students, mostly freshmen, in Syracuse University. The material has been altered many times, but from the beginning it has included a comprehensive review of knowledge and a humanized logic. We were encouraged when this dual combination of studies was later recommended by Committee G of the American Association of University Professors. In the *Bulletin* of this Association for October, 1922, the following conclusions are stated:

> This Committee believes . . . that the endeavor to train the student in thinking is the most important [purpose] of all. . . . The Committee believes also that the endeavor to give the student a sound general conception of the nature of the world and of man is of fundamental importance. . . . We recommend, then, for the freshman year two special initiatory courses. It seems both logical and practically desirable that the course on the nature of the world and of man should precede that in thinking. We recommend that for this course a common text or syllabus be used by all students.

The course as taught at Syracuse University has been presented to relatively small groups of students. Each teacher has had exclusive control of the work of his students, and has discussed or supplemented the textbook to meet their particular needs. General lectures have not been given, although the text is readily adaptable to such a plan. An attempt has been made so to organize the materials as to facilitate their profitable use either in a full-year course or in a one-semester course. In the latter case, certain chapters may be employed as collateral reading. In an appendix may be found for each chapter numerous problems designed for class discussion, oral or written, and at the end of each chapter appears a selected bibliography. We have sought to include those introductory or fundamental books which would be of service in orienting the reader in a relatively new field of knowledge. Chapter notes also contain important reading references which are not repeated.

We have been keenly aware of the difficulties confronting the survey course. We have sought to be catholic in scope without being too impressionistic, and to be exact in detail without becoming pedantic. Our

presentation is necessarily incomplete, but, we hope, not superficial. Each author assumes sole responsibility for the chapters bearing his name.

The dominating purpose of the book is, of course, educational. Our aim, therefore, has been to lead the reader to a better acquaintance with the physical universe, society, and himself, and with the essential methods of trained thought. Parts One and Three consist of an introduction to the major branches of science and philosophy. The point of view, the major concepts, and the special techniques of the great disciplines are emphasized. Part Two is devoted to a critical and systematic statement of the anatomy of scientific procedure. This emphasis upon method is characteristic of the whole work.

Scientific methods were once thought of as the occult practices of initiated magicians. These methods are no longer mysterious, but are a public treasure, thoroughly intelligible, even simple. All those who desire to do so may now possess and enjoy the scientific spirit. It is hoped that many outside of academic halls may gain from the following chapters a clearer appreciation of the fields and methods of knowledge.

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PART I

A SURVEY OF THE SCIENCES

CHAPTER I

THE BACKGROUND OF KNOWLEDGE

1. Introductory

The ancient philosopher, Lucretius (99–55 B.C.), wrote a long poem which he called *De Rerum Natura* (*On the Nature of Things*). His purpose in undertaking this ambitious task was to furnish those who read it with a new attitude toward the world in which they lived. He did this by making a survey of as many aspects of nature as came within his view, giving a succinct and reflective account of the various fields of human knowledge. Where his doctrine was believed, he undoubtedly succeeded in providing a new enlightenment and a new moral freedom. The task of this book is very similar in character. To review the chief aspects of the natural order, and the additions which man has made to it, is to gain a reorientation, insofar as knowledge makes a difference in life.

Furthermore, when a coherent general method of approach is employed, the enterprise of surveying the fields and methods used in contemporary culture may be fairly characterized as philosophical. There is an oft-quoted quip to the effect that philosophy is "a blind man in a dark room looking for a black hat which isn't there." But philosophy has had its defenders outside the ranks of professional philosophers. For instance, Mr. G. K. Chesterton says in a well-known passage of his *Heretics:*

> "We think that for a landlady considering a lodger, it is important to to know his income, but still more important to know his philosophy. We think that for a general about to fight an enemy it is important to know the enemy's numbers, but still more important to know his philosophy." [1]

There is no lack of appreciation of the significant position, in the conduct of affairs, of a total point of view. Since it is the avowed purpose of this book to present a wide survey of much of the material called civilization, to indicate the nature and place of knowledge and its devices in the world which we inhabit, a broad viewpoint is essential. To become intellectually oriented in the world is to become in some sense a philosopher. It is to achieve a total reflective standpoint. The essential business of the philosopher is criticism. Consequently, the purpose of these pages is, innocently enough, to make the reader a bit of a philosopher!

[1] Chesterton, G. K., *Heretics,* New York, Dodd, Mead, & Co., p. 15.

As an aid to an appreciation of the extent and relative importance of the various aspects of civilization, major divisions of human culture will be reviewed and the methods used in them, together with some of the results thus far achieved by their use, will be discussed. The sciences and the philosophical disciplines will claim the most attention, for it is the nature and place of reflective knowledge in experience which chiefly concern us. But any phase of man's life may fall within the scope of our story, and all of it may be fairly sampled by the presentation of characteristic bits.

2. Human Nature and Civilization

What is civilization? What, also, is human nature? We must have some general introductory idea, however vague, of what we are to discuss. When we speak of " the rise of civilization," or the " fall " of a civilization, what is it which rises and falls? When do men become civilized (if, indeed, they are) and how? Are men born civilized?

We can say definitely that men are not born civilized, for by civilization we mean that something is known, or some skill is possessed, beyond the mere native human potentialities. Men are not born into the world as thinking animals, fully trained, but as unformed creatures of impulse. Man's nature is best thought of as a set of tendencies to action, a dynamic complex of potential activities. Although other animals resemble man closely in this regard, man has a great advantage over them in that his impulses are less pre-formed. The looseness with which man's activities are fitted together by nature makes him far more plastic and flexible in his development. He is undoubtedly capable of organizations, both individually and collectively, which history as yet has not recorded. His career is not fixed, as is that, for example, of the hymenopterous insects,[2] and this native lack of determination is one of his most marked biological advantages. It leaves room for cultivation and for thought. Man can learn to be different in his behavior more readily than can any other animal. We define the equipment which man has at birth as his nature. *Human nature is the total of unlearned activities which man progressively unfolds.* Some inborn tendencies, such as the desire for food, are present actively at birth. Others, notably the sex impulse, mature at a relatively late date in the individual's history. But, since they are unlearned, these also are included in the notion of his nature.

Contrasted with man's nature is his civilization, or culture. *Everything which man learns to do from other men is part of his civilization — all*

[2] *Hymenopterous insects:* an order of insects having four membranous wings and mostly a vermiform larva and an inactive cocoon stage, as bees, wasps, ants, etc.

habits, customs, manners, sentiments, and beliefs. It is important for the understanding of man's thought that this double background of thinking be made explicit: (1) a *biological nature* which is impulsive and (2) a *culture* which has been developed and assimilated so thoroughly by man as to become, in some instances, "second nature." Thinking is best regarded as a part of the latter; it is an acquired characteristic and hence part of man's civilization or social inheritance. It is scarcely necessary to argue this point. If thought were not acquired, education would be unnecessary. Culture would flower from man as naturally as saliva flows from his mouth. But, instead of growing a mind as he grows his teeth, man must acquire it, as he does swimming, or flying, or skill at the piano. It is a learned activity, as different from the undisciplined impulsive reactions of his nervous system, out of which it develops, as are the arias of a diva from the mouthings of a female gorilla.

Civilization is accumulative. It brings the past into the present and informs the new life with the experience of its ancestors. The attitudes and habits of others begin to be adopted early in the career of the individual. The child comes to eat three meals a day if his parents do, to wear certain clothes, and to entertain specific attitudes toward certain acts of others. Traditions are picked up from the environment as unconsciously, in some cases, as the air is breathed. French children hate and fear the Germans, and *vice versa,* as Protestants and Catholics hated and feared each other during the religious wars. One's civilization or social heritage is determined by the specific conditions of one's training. If raised on a desert island, a child of even superb heredity would be a mental blank. Nurture would not have supplied it with a civilization or culture. But most men are not juvenile Robinson Crusoes; they have specific nurtures, and the traditions and prejudices of their culture have been absorbed. Men are the creatures of their trainings in that their prejudices and their problems are in large measure set for them. In religion a man is a Christian, a Jew, a Mohammedan, or a Buddhist, for the most part, because his parents were. In politics he is Democratic or Republican, Conservative or Laborite, chiefly for the same reason. He is indoctrinated with beliefs, preferences, tastes, at an early time in his development, when his powers of resistance are low. He picks up habits and ideas uncritically. He does and believes things because others do. He is civilized according to the vogue.

The accumulated material of man's social inheritance is so immense and so central to his life that man today could not live without it. Those who, through nervous disorders, lose their ordered knowledge and behavior, become at once charges on the care of others. Professor Wallas has argued that if, through some metaphysical accident, men should lose their civilization

simultaneously, the results would be appalling.[3] All speaking and thinking would cease. There would be no newspapers, no milk deliveries, no transportation, no artificial light and heat. All knowledge of domesticated plants and animals would be lost. No one would know the meaning of even a water faucet, much less that of a surgical instrument. In any large city the loss of man's civilization would immediately result in fighting at places where food was visible. Continuous violence would go on as men attempted to get food. Perhaps some individual, while fighting, might discover the meaning of a tin can of food and, by virtue of this, gather a group around him which he would feed. Some others might discover how to get water from a faucet and thus put off the day of death. But within a few weeks there would be no one alive in cities such as New York and Chicago. Indeed, the population of the whole civilized world would wither immediately. The first winter would kill all the whites in the temperate zone. Only in the tropics, where bananas dropped ripe into their mouths, would a few whites remain. They, with the tropical blacks who survived, might begin the reconstruction of a civilization. Perhaps the group which would have the best chance of surviving such a loss as that suggested would be the pigmy blacks of Africa. Having less to lose, they would not be so embarrassed by their loss as the more highly cultivated peoples. The latter are so dependent upon their social inheritance that they could not live without it.

The amount of exact knowledge which man's culture contains today is roughly one hundred times that of his forebears of two hundred years ago. This increase in the bulk of material has caused new problems to arise. It is not merely a question now of transmitting a fixed tradition; indeed, it was never that. As this social inheritance of man grows, it must be passed on more and more quickly for fear that it may die. Compulsory education has come as a device to insure a certain minimum amount of popular training and information. Card catalogues and filing systems have helped man to handle an ever-growing mass of knowledge. Knowledge, indeed, has come to mean the ability to find ideas rather than their actual possession.

Departmentalization of knowledge has taken place. *Experts* are here to stay. The vast increase in our knowledge has made it imperative that specialization take place; after a certain preliminary training young men and women proceed to master a specific field. The division of labor which results makes it possible to assimulate the whole body of scientific material as it increases. It is conceivable that human nature may rebel and refuse to transmit this onerous load. Perhaps the " dark ages " in the world's history have been periods in which men did just this thing. Whole peoples

[3] *Cf.* Wallas, Graham, *Our Social Heritage,* Chapter I. The author wishes to acknowledge his debt to Professor Wallas.

seemingly have done what the small boy wants to do in the springtime — play truant and go fishing. By sharing the load, man has made it tolerable, however, and a total eclipse of civilization is now scarcely possible.

It should be noted that alterations, as well as additions, occur in culture. A new element may eliminate a whole field of previous knowledge. Such new items in experience as gunpowder, the printing press, the steam engine, the internal combustion motor, representative government, and the theory of evolution have caused whole areas of previous knowledge to be readjusted. A constant process of reorganization must be carried on, and a slow elimination of outworn knowledge takes place.

3. The Criticism of Tradition

Two mistaken attitudes may be assumed towards the traditions of man's civilization. They may be regarded as good merely because they are old, or as bad because of their antiquity. The total reactionary is, of course, as rare as the extreme radical. Obviously, the uncritical acceptance of tradition and the uncritical rejection of it are both to be avoided. Tradition is neither false nor true *because* it has been handed down from the past. The presumption is that there was some ground in the past for an idea or way of behaving, else it could not have become part of man's culture. What that ground may have been, and whether it still is present, is not always easy to determine. There was a sound basis for the primitive man's prohibition of marriage between kindred, and for his drinking of brewed liquors; but it took modern biological science to make clear that he thereby avoided, in the one case, feeblemindedness and, in the other, typhoid fever. Such prohibitions as that of the Jews concerning the eating of pork, which is a healthful and nutritious food, and such institutions as monasticism, which artificially sterilized the best heredity of generation after generation of men, are unable to stand criticism. The former rests on a primitive taboo and the latter on a misconception of human nature. The critical evaluation of tradition must take place as man's civilization is assimilated in each generation. Only in the light of an intelligent analysis of the situation can the question as to the retention of a tradition or way of behaving be answered. One cannot say that all of tradition is true because some of it is. Nor is all of it false because part of it has been found so. There are relatively stable elements in every part of man's culture, and there are other parts which are moving rapidly, as their revision goes on. It is desirable that the young should assimilate as quickly as possible the valuable core of tradition, and then proceed, in the field in which each specializes, to keep abreast of the changes which are taking place. The bulk of man's knowledge is so large, however, that it is the rare

man today who gets to the real frontier of knowledge in any field. The mass of mankind must always take the word of someone else.

The critical treatment of traditional knowledge in any situation would illustrate some of the difficulties of correct thought. Man is inveterately prejudiced. Ideas take hold of him before he is aware of them and, like the man in Molière's play who was astonished to discover that he talked prose, men frequently wonder at the things which they have believed. To assume an attitude of approval or rejection without an adequate reflective consideration of the grounds of action is to become prejudiced. Because of laziness or lack of time, natural stupidity or environmental deficiency, men may become merely bundles of undisciplined prejudices. Various impulses and tendencies are loosely guided by uncriticized symbols with emotional associations. The average man, through his habitual prejudices, can be played upon by a skilful speaker or writer almost as readily as a musical instrument can be played upon by a virtuoso. Soaps and automobiles are bought because they are so well spoken of in the advertisements. Men vote for political candidates for the same reason. And men will fight for their prejudices. Man's active nature takes up a position and then his intelligence will exhaust its resources in the defense of that prejudice. It is like falling in love. First one does it, then one compliments oneself on being so clever as to distinguish such a remarkable mate, and ends by congratulating oneself and one's family on one's rare judgment. It was not judgment at all; it was passion, impulse, prejudice. Reason came in only as an apologist, *ex post facto,* to justify the position already taken. Much of man's thinking goes on in exactly this way; we may say that the sum total of a man's habitual prejudices is his "viewpoint." When a man says that another is "right," he means that the man in question has the same stock of prejudices which he himself possesses.

4. Prejudice and Propaganda

The recognition of the irrational character of much that passes for thought involves an appreciation of the practical importance of the cultural background. Men of similar breeding respond to similar appeals. A common background gives homogeneity of taste and feeling to a group. Geographical, professional, and national groupings are evidences of this. Many dangers lurk in the control which passion and prejudice exercise over thought. When Hume said that "reason is the slave of the passions" he spoke the truth, but he might have added that slavery should be abolished. Our ends grow naturally out of our irrational aptitudes. But reason must criticize those aptitudes in terms of their ends. To be merely intelligent is to be cold; to be merely passionate is to be brutal. Attachment is neces-

sary if man is to have purpose; detachment is essential if he is to have perspective. When passion is unenlightened by reason, the individual man may become a tool to the ends of others. *Propaganda* is the name given to the deliberate using of others, by means of their prejudices, for ulterior ends of which they may be unconscious or only dimly aware. The technique of popular appeal is familiar enough. Successful preachers, lawyers, chautauqua lecturers, salesmen, and politicians are experts in using it. The trinity of appeals, " heaven, home, and mother," is always effective in securing the approbation of a popular audience. Tell a man what he already thinks and he will approve of you. The candidate for political office, for example, is ostentatiously orthodox to as many groups as possible. He speaks to women's clubs about the wonders of American womanhood, to church audiences about the Bible as the " good old Book," and to fraternal orders about their various purposes with covert allusions to their respective rituals. He joins all the societies he can; he becomes a " joiner." His purpose is to get votes for himself. When the real political issues are divisive, he uses the general prejudices of his hearers as a means of organizing their support. The chairman of a national political committee obviously must be an expert in applied mob psychology; the bishop, the moderator, and the pope of a church must be the same. Even the salesman of fake oil or mining stock usually knows enough about human prejudices to show pictures of his wife and children to his victim, or to talk approvingly of the victim's religious or political beliefs.

It is notorious that passion and impulse plunge men into actions which turn out to be harmful and disgraceful. The instinctive equipment of man forms the framework for the problems of the moral life. Men must realize that their passions and prejudices are just as misleading in other fields as in that of their more overt conduct. An impulse or prejudice may be right or may be wrong in the particular situation. The fact that one possesses it, however, is no evidence that it is one rather than the other. Continual criticism is necessary. Man's instinctive equipment was forged in the struggles of the late Tertiary period, when he hunted, fought, and fled in herds. The translation of this archaic equipment into the modern world causes all kinds of difficulties. There is evidence that men occasionally revert to primitive herd methods. The pack may go hunting as in primitive days. Lynchings, reigns of terror, and similar mob occurrences are part of a tremendous mass of evidence, which history and psychology afford, to the effect that when man allows undisciplined impulse to sway him he is little better than other animals. In questions of knowledge and conduct, therefore, it is the business of intelligence to build up a technique of a superior sort, with checks and balances which afford man a chance to choose the best rather than merely to blunder. Scientific method aims to

free man from the dominion of prejudiced bigotry and uncritical blindness. Some one has defined a bigot as "a man who opens his mouth so wide that he can't see out of his eyes." Science aims to close the mouth and open the eyes. To become aware of one's prejudices is, in some sense, to be emancipated from them; to know one's passions is to control them. The aim of education is to substitute rational ways of doing things for instinctive and habitual ones, to substitute intelligence for passion and prejudice as a means of control. Perhaps man will continue to do the same essential things which he has always done, but he will do them differently, and in that difference there is ground for hope. Where consequences are obviously undesirable, rational man can veto the impulse to action. Where there is merely prejudice, judgment can be withheld.

5. Specialization and Authority

Specialization has been mentioned as the result of a division of labor forced upon men by the growth of our civilization. Experts are specialists and their statements carry, *in their respective fields,* a weight to which an untrained man cannot aspire. An authority is an expert. The ability to recognize authoritative books and men should be one of the fruits of education. It is clear that an expert must have had adequate opportunity for personal experience of the facts in question in any field; his authority is proportionate to the scope and adequacy of his experience. No rational man with a sick child would think of calling in a plumber rather than a physician. Yet leaky plumbing might cause the plumber in turn to become indispensable to a family. Again, a man is not an authority on the stock market because he is a champion tennis player. Nor is some ex-politician an authority on the biological doctrine of evolution. There are always men who wish to pose as authorities in fields in which they are perhaps not even novices. The fact that a man may be a great inventor does not mean that his opinions on education are worth, necessarily, any more than those of a garbage collector. In the mass, mankind has not yet seen the implications of specialization and technical training. Men go to dentists to have their teeth filled and have electricians wire their houses, but they elect inexperienced small-town lawyers to the Presidency and take chautauqua lecturers and venal newspaper editors as their authorities in economics, religion, and international affairs. But the prestige of an authority should carry no weight beyond *the particular subject in which that prestige has been empirically established.*[4] The authority of a writer or speaker in any field must be regarded as a function of his direct knowledge. His prestige in other fields is irrelevant.

[4] *Cf.* Montague, W. P., *The Ways of Knowing,* pp. 39 f., for an excellent account of authoritarianism.

Authority, thought of as a source of knowledge, always rests its claim ultimately upon somebody's direct knowledge. It is, therefore, only secondary in importance. The claim that thousands believe something to be true, and that therefore it must be true — the authoritarian appeal to the criterion of *numbers* — adds weight to an argument only when the ultimate source of knowledge is recognized as something other than authority. The same is true of the appeal to the criterion of *age*. The antiquity of an idea is no proof of its truth unless it can be shown that somebody, somewhere, had *direct knowledge, i.e.,* verified the theory scientifically in his own experience. Ideas, like paste jewels, may be current for years among thousands until their falsity is ascertained by the scientific tests of the expert. Authority in knowledge is always a function of expertness. When there is reason for doubting the veracity or the competency of witnesses, the question of their authority must be taken up. The bulk of our knowledge as individuals is derived, however, from the testimony of others — testimony which, for the most part, is unimpugned.

6. Collective Rationality

This chapter has had to do with the social background of thinking, with man's native equipment, its habitual, irrational organization, and with the passing on to posterity of the habits and notions inherited from the past. Subsequent chapters will indicate the exact techniques of scientific thinking. It is fitting that it should be noted here, in conclusion, that man is like certain species of trees which occur only in forests. His functions can reach their highest fruition only in the society which conditions their development. Rationality, instead of being a sporadic, aristocratic achievement in society, as it has been in the past, is being undertaken more and more as a deliberate collective enterprise. Certain forms of social coöperation, notably democratic government, demand a *thinking together* on the part of many men. In the attempts at collective thinking, such as occur in the solution of group problems by deliberative assemblies, certain general conditions of success have become evident. The individuals composing the group must (1) *be frank and express their notions* with complete candor. Lack of frankness is an evidence that an ulterior purpose is in view, and the collective goal is, of course, tacitly denied. " Open covenants openly arrived at " cannot be reached by individuals who are secretly grinding the axes of their private interests. The second rule is (2) *that no more value must be attached by the individual to his own views than to those of others.* Infallible authorities cannot deliberate. Every member of a group attempting to coöperate in thought must recognize that he is as likely to be wrong in his opinions as another. The argument must be

followed, in the words of Socrates, whithersoever it leads. Collective deliberation is a process requiring good humor and good will. Thought cannot prosper in any other atmosphere. It is trite to say so, but in every important deliberative assembly in the world at present these two rules are violated almost daily.

We pass now to a specific study of the chief sciences. We shall study mathematics, the physical sciences, biology, psychology, history, and the social sciences before taking up, in Part Two, the study of scientific method as a separate consideration. The third and last part will be a brief discussion of the other philosophical disciplines.

P. W. W.

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CHAPTER II

MATHEMATICS

1. The Main Characteristics and Divisions of Mathematics

Mathematics has been often lauded as the model science because it has perfected the logical virtues of exactness, certainty, and systematic reasoning. Our occidental esteem for these excellences of intellect is a precious gift of the Greeks to our civilization. Plato inscribed this condition on the door of his Academy: "Let no one enter here who is ignorant of geometry." The fine qualities of intelligibility in mathematics are not to be explained by any mysterious mode of reasoning, but rather by the following features.

First, the subject-matter treated by mathematicians is explicit. They deliberately deal only with concepts, such as number, space, time, and function, which admit of precise determination. Also, for many of their definite ideas, they have invented and conventionalized unambiguous symbols. These signs make possible a lucid and economical representation of ideas, as well as a facile manipulation of them. Further, mathematicians lay down in advance, as exactly and fully as possible, the precise procedure which must be followed in their complicated chains of reasoning. Having strictly set forth their basic assumptions, they play their game with as much logical rigor and technical dexterity as they can. Mathematical mistakes arise largely from such psychic limitations as inattention or forgetfulness, lack of skill or ignorance. Finally, the results of mathematical reflection are organized into elegant systems of logical demonstration. Thus, *in the mathematical domain clearness, cogency, and order attain superlative expression.*

In consequence of a rich, cumulative history, coëval with civilization itself, mathematics today presents a staggering diversity and vastness. Its colossal subject-matter has been reduced to thirty subdivisions by a committee of experts representing the Royal Society of London.[1] Convenience and history, rather than logic, warrant a grouping of these many phases into five grand divisions. The following scheme suggests several relations of kinship and dependence:

[1] See *International Catalogue of Scientific Literature,* London, 1917, Division A, Vols. XIII and XIV.

Mathematical or Symbolic Logic

Arithmetic and Algebra — Geometry

Analysis

Applied Mathematics

We shall now seek some glimpses of the meaning, utility, and grandeur of mathematics by modestly examining a few of its principles. A proper appreciation of its spirit and abounding vitality is reserved for lifelong votaries.

2. Arithmetic, Number, and Infinity

The most ancient and mysterious concept of mathematics is number. The great mathematician, Minkowski, has declared that "integral numbers are the fountain-head of all mathematics." Early in life, in the familiar art of arithmetic, we acquire a superficial acquaintance with number. It had its practical origin in man's effort to count his treasures and measure his land. It is a kind of order generated by the mind in its endeavor to dominate a world that is crowded with a multitude of objects. Numbers are threads of thought, spun by man's abstracting intellect, upon which he can string any kind of objects.

What, then, is the key to the riddle of number? Modern mathematicians give a simple answer: *the idea of correspondence.* Let us assume — the invariable prologue of the mathematician — that we know what a collection or class of things means. Let us imagine, for example, that we have a group of students and a set of chairs, and that we can assign the chairs so that no unseated students and no empty chairs are left. We have exhaustively correlated the two sets of objects. The students and chairs are said to possess a one-to-one relation or reciprocal correspondence. Although they are strikingly different beings, they actually have something in common which we may call a type. Similar coördinations may be set up without remainder between this class of students and other collections of objects, such as hats, fathers, or dance partners. Indeed, a multitude of assemblages may be found which correspond in this way; they are equivalent in the sense that they embody the same type. This recurring type or common characteristic is the *number* of elements in each of these aggregates. We ascribe to them all the identical cardinal number, and to this number we assign for convenience an arbitrary symbol, as 9, or nine.

Let us suppose, however, that some students have no chairs or that some chairs are unoccupied. This result obviously means that there are other types or classes which cannot be perfectly coördinated with nine. Some are smaller; many are greater. An unlimited multitude of types of

aggregates in fact exist. These types are the familiar cardinal numbers. To extract these numerical similarities from utterly different things represents acts of abstraction that are difficult for primitive man with his concrete concerns. "It must have required many ages to discover that a brace of pheasants and a couple of days were both instances of the number two."[2] In pure arithmetic, however, all reference to persons or chairs, fingers or hours, apples or planets, is omitted. Arithmetic is a highly abstract study of the varied properties and kinds of numbers, and of the relations and laws which subsist among them. Arithmetic is also the art of performing upon numbers a host of operations which aim at determining one quantity by its relations to others.

The cardinal numbers may be ordered in countless ways. A very important arrangement is the common or natural order; it is called "well arranged" because the lesser always stands before the greater. This series, like many other remarkable *series* found in mathematics, is constituted by a law which is common to all its members. This law uniquely determines the value or position of each term in relation to two others. The ordinal series is a linear sequence of unequal numbers such that each is one greater and one less respectively than its two neighbors. Here is a law by which an endless succession of continually new numbers may be generated. By this prophetic progression we may attain any conceivable magnitude, and then increase it as much as we wish.[3] The ordinal numbers are related to the natural order of cardinal numbers as adjectives to nouns; one, two, three, etc., become first, second, third, etc.

The cardinal numbers form an infinite class. "The difference," says C. J. Keyser, a distinguished American mathematician, "between a sequence that stops somewhere and one that has no end is awful. No one, unless spiritually unborn or dead, can contemplate that gulf without emotions that take hold of the infinite and everlasting. . . . One of the grand achievements of mathematics in the nineteenth century is to have defined infinitude and to have discovered that infinites rise above infinites, in a genuine hierarchy without a summit."[4] This pregnant discovery which gives a precise meaning to the elusive infinite is that *a collection of elements is infinite when the number corresponding to a part of itself is equivalent to the number corresponding to the whole.* Thus, all the even

2 Russell, Bertrand, *Introduction to Mathematical Philosophy*, London, Allen & Unwin, 1919, p. 3.

3 *Cf.* Moritz, R. E., "The Meaning, Methods, and Mission of Modern Mathematics," *Scientific Monthly*, May, 1928, pp. 414 ff.

4 Keyser, C. J., *The Human Worth of Rigorous Thinking, Essays and Addresses*, New York, Columbia University Press, 1916, pp. 90 and 98; quoted with permission of publishers.

integers may be put into one-one correspondence with all integers, as follows:

$$\frac{1,\ 2,\ 3,\ 4,\ 5,\ 6,\ 7\ \ldots}{2,\ 4,\ 6,\ 8,\ 10,\ 12,\ 14\ \ldots}$$

In a similar way, there are infinite points in the segment of a continuous straight line, for after taking away points to match all positive numbers, we find that an infinitude of points remains. Thus, in an infinite assemblage one can take away a part without diminishing the number corresponding to the whole. Euclid's axiom that " the whole is greater than a part " does not apply strictly to the numbers corresponding to infinite wholes: his statement is too general; it must be restricted to finite numbers.

Dr. Roe has pointed out that two main conceptions of the mathematical infinite may be distinguished, the variable and the absolute infinite.[5] Neither, of course, is actual or expressible in any number; both are creations of abstract thought. According to the first conception, " the infinite is a variable which increases without any finite limit." It is endlessly growing or becoming; it cannot stand still; if it is stopped at all, its essence is destroyed. The variable infinite approaches the absolute infinite as a limit or conception which completes our thinking. " The absolute infinite is the totality of all possible magnitudes that can be conceived."

The number theorist, in characteristic mathematical fashion, constructs number system upon number system. From whole numbers he goes on to fractional, negative, irrational, imaginary, and complex numbers, algebraic variables, and many other extraordinary varieties. Beyond finite numbers he builds transfinite ones of astonishing magnitudes. The first transfinite cardinal number is the cardinal and infinite number of all finite numbers.[6]

We have seen that a finite cardinal number is the common type belonging to all the collections that admit of exhaustive mutual coördination. It is *" a class of equivalent classes,"* as two is the class of all couples and twelve of all dozens. *Number in general is the class that comprehends all types thus described.* We have left far behind the chairs and students, the concrete world of perceptions, from which we started on this intellectual flight. We have penetrated the domain of pure thought where the mathematician dwells, and where he enjoys a marvelous freedom and flexibility in producing and manipulating his concepts. Yet in the midst of his infinite and exhilarating creations he rarely suffers intellectual vertigo, for his express principles and orderly procedure ever give him steadiness and balance. Indeed, his principles and methods are the sources of his power.

[5] Roe, E. D., Jr., *The Mathematics Teacher,* 1910, Vol. III, pp. 44 ff.

[6] *Cf.* Alexander, H. B., *Nature and Human Nature,* Chicago, Open Court, 1923, Ch. IX, " The Definition of Number."

3. The Decimal System of Notation

While the number series is infinite, economy in representation and learning demands a small number of signs. Our arithmetic system employs only ten symbols, the well known Arabic figures of our childhood arithmetic. While twelve or fifteen might be a more convenient base today, we reckon by tens because, as we learn from anthropology, our savage forefathers acquired the habit of counting on their fingers, an ever-present and unchangeable abacus.

Ten, however, is only one of many bases that have been used. Among American Indians bases of three, four, five, eight, ten, and twenty (fingers and toes) have been found. The Babylonians employed a system with a radix of sixty, which we have borrowed for measuring the degrees of circles and smaller periods of time. One of their tablets, written before 1600 B.C., contains such equations as $1 \cdot 4 = 8^2$, which is unintelligible unless 1 stands for 60 by virtue of its position.[7]

An analysis of our decimal system will explain its remarkable power of representing a number of any size whatever by means of only ten signs. The signs have been called the proper names of numbers. To a nameless Hindu of an unknown time is due the credit for perfecting this grand symbolism in which zero, ten, and position are so fortunately combined.

When any of the digits, 1 to 9, are placed side by side, they acquire by convention important new values; namely, successive multiples of ten. In the first position at the right they have their original cardinal significance. In the next position to the left any figure has 10 times its primary value; in the third, 100 times, and so forth. In such a local or place system, 23, for example, means $2 \times 10 + 3$. When a position is empty, the remarkable symbol for zero is inserted to maintain proper order. Thus 609 means $6 \times 10^2 + 0 \times 10 + 9$. A useful convention makes 10^2 (the second power of 10) signify 10 times 10; 10^3 signifies $10 \times 10 \times 10$, etc.

The preceding analysis may now be illustrated in the following way: 69475 is the abbreviation for:

$$10^4 \times 6 + 10^3 \times 9 + 10^2 \times 4 + 10 \times 7 + 5$$

It will be noticed that each power in this sequence is equal to the number of following positions. Every digit, then, has as many values as the inexhaustible positions which it may occupy. This scheme of notation is simple, tremendously economical, beautifully systematic, infinitely progressive, and always applicable to any countable objects whatever. To test its value

[7] Cajori, F. A., *A History of Mathematics* (ed. 2), New York, Macmillan, 1926, pp. 5 and 88.

one may try to calculate in the Roman symbolism how much XXVIII dozen eggs would cost at XLII cents a dozen.

4. Some Principles and Methods of Algebra

We have noted that many bases or radices other than ten have been used in counting. A general formula for all varieties of notation may be constructed by letting r represent any radix and a_1, a_2, a_3 . . . certain digits. Thus, in the decimal system r equals 10, while a_0, a_1, a_2, a_3 . . . are among the digits, 1, 2, 3 . . . 9. Let us add the convention that juxtaposition of letters means multiplication. In a place system, then, any whole number r may be represented by the following summation series: [8]

$$N = a_0r^n + a_1r^{n-1} + a_2r^{n-2} + \cdot \quad \cdot \quad \cdot + a_n$$

If we let b_1, b_2, b_3 . . . represent numerators of any possible values, we obtain the following series, from which a number of any magnitude, however small or great, may be derived:

$$N^1 = a_0r^n + a_1r^{n-1} + \cdot \quad \cdot \quad \cdot + a_n + \frac{b_1}{r} + \frac{b_2}{r^2} + \frac{b_3}{r^3} + \cdot \quad \cdot \quad \cdot + \frac{b_n}{r^m}$$

This formula beautifully illustrates several tendencies of mathematical method: penetrating analysis in search of elementary concepts and underlying laws; the resulting precise and orderly expression of conclusions; generalization "to the utmost serviceable limit."

The symbolic transformation just achieved typifies a transition of tremendous significance in mathematical history. Definite and fixed quantities have become indeterminate or variable ones. The indefinite letters of the alphabet are admirably fitted to symbolize these novel and potent terms. The concept of number is thus immensely enlarged. Millions of special cases may be covered at once by the use of literal formulas. *Algebra* has been born: it is *generalized arithmetic.* Sir Isaac Newton called it "universal arithmetic." It employs all the operations, integers, signs, and axioms of arithmetic, and many more in addition, notably negative numbers. A Hindu named Bhaskara, of the twelfth century, described it as "a facile method of calculation, charming in its elegance, clear, concise, correct, sweet, and agreeable to learn." [9]

The most original feature of algebra remains to be indicated. Having dared to operate upon unknown quantities as if they were known, the algebraist becomes indifferent to the meaning of his terms. Because a

[8] Roe, E. D., Jr.; *cf.* Wundt, W., *Logik* (ed. 4), Stuttgart, Enke, 1920, vol. II, pp. 147–150.

[9] Boutroux, Pierre, *L'Idéale scientifique des mathématiciens,* Paris, Alcan, 1920, p. 88.

variable may stand for any one of an endless range of values, the pursuit of these particular values is unattractive. A constant, then, may be conceived as a variable whose range consists of a single number. He turns his attention in a new direction: to the formal mechanism for combining and transforming symbols. The contemporary algebraist is much less interested in erecting complicated edifices than he is in devising sure rules of procedure. *Algebra, then, is the science of the operational combination of symbols according to previously prescribed rules.*[10] Its point of view and ideals dominate pure mathematics.

Algebra is a highly developed and powerful technique of combinatory calculus. It is an assemblage of rules and formulas that claim to operate rapidly, surely, almost mechanically. It has been called the *ars magna.* Its utility is extensive in science and practical life. By its methods a multitude of problems may be readily solved which otherwise would be difficult or impossible of solution. Algebraic formulas may be built, as in natural science, architecture, and engineering, which may be deductively applied to innumerable concrete cases through the simple substitution of any particular values that happen to be concerned.

The rules for executing combinations in elementary algebra are evidently of fundamental importance. The various fields or kinds of algebra are differentiated by the rules prescribed in their initial postulates. The basic rules of transformation are simply definitions of the principles that are implicit in arithmetic operations. They are epitomized in the statement that the factors of a sum or product may be put together in any order one pleases. This statement is commonly expanded in the five primary formulas that follow. These apparent tautologies quickly lead to far-reaching and surprising affirmations. They typify the union of freedom and necessity which characterizes mathematical reasoning.

$a + b = b + a$	(Addition is commutative)
$(a + b) + c = a + (b + c)$	(Addition is associative)
$a \times b = b \times a$	(Multiplication is commutative)
$(a \times b) \times c = a \times (b \times c)$	(Multiplication is associative)
$a \times (b + c) = (a \times b) + (a \times c)$	(Multiplication is distributive with respect to addition)

It is important to note that the preceding rules apply only in the most elementary traditional algebra. Different prescriptions characterize other and higher types. For example, the commutative law for multiplication does not always hold in quaternions. If p and q are quaternions, then

[10] Suggested by Roe, E. D., Jr., "A Survey of Mathematics and Astronomy," *Scientific Monthly* (1923), Vol. XVII, pp. 246–247. *Cf.* also Pacotte, Jules, *La Pensée mathématique contemporaine,* Paris, Alcan, 1925, pp. 18–24.

pq is not necessarily equal to qp. The law for addition, however, does hold: $p + q = q + p$. In short, each algebraic system is fixed by the particular set of operational principles which are assumed as its foundation. The algebraist may prescribe a set of axioms which is different from any traditional system in order to ascertain what interesting conclusions may follow from them.

The preceding axioms describe varying conditions under which quantities are equal. A statement of equality between two numerical or algebraical expressions which are not identical is called an *equation*. The equation is the ubiquitous organ of algebraic history, theory, and procedure. To solve a problem algebraically, one first translates it judiciously into the compact language of the equation. The hypothetical unknown is usually represented, as Descartes suggested, by x, y, or z. Then, by successive transformations of the equations, one seeks a line of connection or equality between the unknown and the given quantities. The transformations are made by substituting equivalents under the guidance of accepted axioms and known relations.

Algebraic calculation is a continuous exhibition of beautiful specimens of reasoning. Here thinking is found in typical form: the methodical search for an unknown term by analyzing and combining in novel ways what is already known. The organic nature of inference stands out boldly: in inference we bind factors together into a system which they themselves imply but had not found. A perfect example of this interdependence is *the function, a variable quantity whose value, or values, depends upon another variable.* Thus, in the uniform motion of a train the distance is a function of the time. An important phase of algebra is the study of constant relations which may exist between variables.

5. The Historical Beginnings of Geometry

Reasoning in geometry closely resembles that in algebra. Geometry has been conceived traditionally as a science of spatial relations, or extended figures, such as lines, surfaces, and solids. The geometer, however, is concerned exclusively with the ideal properties of figures as defined by thought and remains utterly indifferent to any physical properties they may happen to possess.

Geometry has a long history beginning in the ancient civilizations of Chaldea and Egypt. In these countries it consisted of a collection of experimental rules which had developed out of wrestling with practical problems of land measurement. The Egyptian surveyors labored under the annual necessity of marking out the rectangular farms obliterated by the Nile, of apportioning legacies, and of laying foundations for build-

ings and monuments. They were called rope-stretchers, for they knew how to construct a perpendicular by stretching, into a right triangle, a rope so knotted that the sides had the proportion of 3 : 4 : 5.

To the Greek mathematicians goes the honor of raising geometry to a strictly theoretical level. From a utilitarian concern with particular cases they turned to prove propositions about *any* figures, or about typical ones, by reference to fundamental principles. The greatest of them looked down with superb contempt upon those who used mathematics for measuring fields and trafficking in merchandise. Plato (427–347 B.C.), in the seventh book of his *Republic,* teaches that numbers and geometry have the virtue of lifting the soul from barbarian clay and the sphere of perishable things into the pure contemplation of eternal verity. Indeed, geometrical reflection is the continual occupation of deity. In order to have a science, he declares, we must be able to give reasons for our conclusions.

The significant steps in the history of geometry are marked by the discovery and proof of important theorems and by the finding of new methods. There was a time in ancient Greece when the news of such a discovery spread swiftly from town to town and was redemonstrated in the sands of every market place. When Pythagoras (580–500 B.C.) found the famous theorem concerning the square on the hypotenuse of a right triangle, he was so " jubilant over his great accomplishment that he sacrificed a hecatomb to the Muse who inspired him." [11]

A succession of discoveries by many geometers furnished materials for the " mathematical Bible " of Euclid (who flourished about 290 B.C.). His immortal merit is that he first organized geometrical propositions into a rigorous deductive science. Although his proofs are not free from errors and tacit assumptions,[12] he created an ideal of exact scientific demonstration and system which has abiding value. His system is the original example of what is called postulational thinking. Keyser declares that " when it was produced, it was so incomparably superior to any other product of human thinking that men were dazzled by its brilliance; they failed to perceive that its significance was not geometric but methodological." [13]

6. The Postulational Basis of Geometry

Geometry as it exists today is a highly developed deductive science. The modern geometer, after the manner of Euclid, demonstrates conclusions

[11] From Cajori, *A History of Mathematics,* p. 2. Copyright 1926 by the Macmillan Company. Reprinted by permission.

[12] See Russell, Bertrand, *The Principles of Mathematics,* Cambridge University Press, 1903, pp. 464–467.

[13] Keyser, C. J., *Thinking about Thinking,* New York, Dutton, 1926, p. 25.

by chains of strict inference from undisputed evidence or premises. These premises are of two kinds: (1) a small number of primitive notions which are very explicitly laid down in advance, and (2) propositions that have been proved by reference to the presuppositions. The resolute ideal of the geometer is to start with such a set of first principles that he can derive from them by logical evolution the whole body of his system without any appeal to perception or other principles. His presuppositions should be as few as possible; that is, everything is to be proved that can be proved.

His initial notions are of two kinds. First, he selects a set of primitive undefined concepts by which every other term is to be defined. These original ideas are so perfectly simple and clear that no other ideas exist in terms of which they could be made clearer. Logical analysis and definition of them, therefore, are at once impossible and needless. Secondly, he formulates a set of primitive undemonstrated propositions, called postulates, which alone furnish reasons for all other propositions. *A postulate is a proposition agreed upon or demanded as a basis for future reasoning.* Postulates that are relatively simple and commonly employed, or that are supposed to have had an empirical origin, are often called *axioms*. Axioms are no longer regarded as self-evident or unalterable.

7. Mathematical Demonstration

According to the accepted rules of his science, the mathematician may have recourse to concrete experience only for suggestions and illustrations, but never for evidence. To become scientific, theories and intuitive insights must be transformed into reasoned arguments. In other words, they must be shown to be logical consequences of approved propositions and of *these alone*. *Demonstration is the name for a chain of rigorous deductive inferences.* It is the most distinctive feature of mathematical procedure. In traditional geometry, demonstration often advances through four stages:

1. General enunciation of the theorem;
2. Drawing of a figure and particular enunciation in terms of the figure;
3. Proof proper;
4. Deduction, perhaps, of corollaries, and addition of remarks.

From this model we may pass on to note two characteristics of mathematical demonstration in general.

First, the mathematician does not seek evidence beyond the express premises with which he starts. He strives scrupulously to avoid all inadvertent borrowings from sense experience and to seize all furtive assumptions. He properly ignores as irrelevant all questions of accuracy in perception which empirical truth seekers must carefully consider. The

diagrams he draws do not furnish reasons for his conclusions, but may suggest fruitful analogies or possible lines of proof. Crudely drawn figures may disturb one's esthetic sense but they lessen the force of one's demonstration not a whit. Social revolutions, dark ages, or convulsions in nature do not alter or disturb the "stable world of concatenated truth" in which he dwells. Mathematics is not an existential science. Of all sciences it is the most self-sufficient and autonomous.

Second, mathematical demonstration consists of a chain of inferences which make clear how the theorem or conclusion necessarily follows from explicit propositions already assumed or proved. The necessity of the inferences is due to the deductive nature of mathematics. Every step must be rationally justified as a definite consequence or instance of the premises. The steps should be as few, precise, and simple as possible. Much of mathematical reasoning consists in finding and substituting equivalents according to prescribed rules. The one touchstone of validity in mathematical thinking is the internal consistency, the solid coherence, of the interlinked propositions.

8. Various Geometrical Systems

A set of original assumptions, together with the conclusions that have been inferred from them, may be organized into a more or less extensive system. There are as many systems of geometry, indeed of mathematics in general, as there are sets of postulates that are consistently developed. The variety of abstract geometries which are possible is inexhaustible. Since the beginning of the nineteenth century many attempts have been made to isolate the basic notions of geometry, and numerous systems have been developed.

One of the most perplexing and celebrated postulates is the parallel postulate of Euclid, which has been condensed thus: "Two straight lines which cut one another cannot both be parallel to the same straight line." By this axiom Euclid proved that through any point outside a line one and only one parallel can be drawn. After more than two millennia of stubborn but fruitless endeavors to deduce this assumption from others, two young mathematicians, N. I. Lobatchevski (Russian, 1793–1856) and Johann Bolyai (Hungarian, 1802–1860) boldly proposed, at about the same time, to build a geometry without that postulate. Contrary to Euclid, Lobatchevski assumed that through a given point an indefinite number of straight lines can be drawn which nowhere will meet a given straight line in the same plane. At the outset he probably expected his novel proposition to lead to contradiction and chaos, and thereby furnish an *indirect proof* of Euclid's postulate. The astonishing result was that actually no contradiction could be made to appear. Instead he discovered, about 1829, a

perfectly consistent, beautiful, and fascinating new geometry. G. F. B. Riemann (German, 1826–1866) set forth in 1854 a geometry whose assumptions permitted no parallel to a given straight line.

In the system of Riemann the sum of the angles in a triangle is always greater than 180 degrees; in that of Lobatchevski, it is always less; in both, the angle sums vary with the area. Again, it is well known that like figures of various sizes can exist in Euclidean geometry; this is impossible in non-Euclidean geometry. It is instructive to note that the geometry of navigation is a two-dimensional non-Euclidean geometry of the Riemann type. A straight line between two seaports on a projection map may not really be the shortest distance between them. A ship from San Francisco to Tokyo does not sail straight west, but follows a northern course which bends towards Alaska. Because curvature is always involved in non-Euclidean geometries, they have been called " curved " geometries in contrast with the " plane " geometry of Euclid. As the curvature becomes less and less, these other geometries approach Euclidean geometry as a limit.

The demonstration of various non-Euclidean geometries has had such notable consequences that Lobatchevski has been called the " Copernicus of geometry." The age-long confidence in the absolute truth of Euclid was deeply shaken, and axioms ceased to be self-evident. In fact, we now know with certainty that the parallel postulate cannot be proved. Geometry becomes fully emancipated from the empirical world and from a single fixed set of assumptions.

Further, it can no longer be said that Euclidean geometry has the advantage of describing most perfectly the spatial world of physical science. To inquire whether the geometry of Euclid or Lobatchevski is truer is as absurd, says H. Poincaré,[14] as to ask whether measurement by meters or by yards is truer. These and other systems are all true in the sense that they are consistently reasoned wholes. In fact, ultra-refined observation and the theory of relativity have revealed a physical world which is slightly non-Euclidean. " Our real world appears to be one of the dream-worlds whose possible existence mathematical genius foresaw." [15]

The conception of geometry, therefore, must be enlarged to include the study of all possible spaces which the mind may construct. These conceptual spaces are not to be perceived, but thought and explained by relevant postulates; implications, not intuitions, yield insight. As d'Abro declares: " Mathematical space is amorphous; it possesses no intrinsic metrics, and our choice of standards of measurement is largely arbitrary. As a result, absolute shape, size, and straightness are meaningless con-

[14] *Monist,* 1898–1899, Vol. IX, p. 42.

[15] d'Abro, A., *The Evolution of Scientific Thought from Newton to Einstein,* New York, Boni & Liveright, 1927, p. 37.

cepts."[16] Albert Einstein (German, born 1879) has shown in his theory of relativity that if two systems of reference are in relative motion, the time and space intervals of one will not be the same when applied to the other; lengths must be decreased and durations increased according to a precise mathematical formula. It follows that there is no universal yardstick or second, no absolute "now."

The consistency of Euclidean geometry is proved by the lack of contradiction in the number system, because every Euclidean proposition may be expressed in algebraic language. Leibniz discovered the kinship between spatial figures and numbers, and defined space well as "the order of coexisting things." The potent combination of geometry and algebra is called analytic, coördinate, or metric geometry. Thus, the square of a number may be made to stand for a geometrical square. It is well known that any point in a curve may be represented by a pair of numbers, x and y, called coördinates. By multiplying and combining coördinates algebraically, the mathematician may create an unlimited geometrical world which sense perception would never reveal.

9. Symbolic Logic

The recurrence of problems in algebra and metric Euclidean geometry points to a common logical foundation. Are there not some principles, for instance the laws of inference, which are inherent in all mathematical systems? Do not similar axioms recur in various sets of postulates? In modern times mathematicians have penetrated far in their search for the simplest primary concepts and relations underlying all mathematics. This analytic and comparative research has been called the algebra of logic, mathematical logic, and other names. Logicians have also sought the presuppositions and rules of all thinking whatsoever. To make their formulations more compact and unambiguous, some have made extensive use of a sign language after the manner of the algebraist. This study has been called symbolic logic, or logistic. *It is a systematic investigation of the chief possible forms of order or relation, especially of those employed in mathematics and the exact sciences.*

In symbolic logic mathematical and philosophical interests meet. The quest for ultimate concepts joins with the use of technical symbols and rigorous methods. As algebra generalizes upon arithmetic, logistic generalizes upon the several parts of traditional mathematics and logic in the search for what G. W. Leibniz (German, 1646–1716) called "the universal principles of all branches of reasoning." Bertrand Russell asserts, "The fact that all mathematics is symbolic logic is one of the greatest discoveries of our age. . . . Both rest upon a single foundation. . . . There are, I

[16] *Idem*, p. 47.

believe, no primitive ideas in mathematics except such as belong to the domain of logic." [17] From the standpoint of the symbolic logician, mathematics is a department or an extension of logic, and is to be developed by a symbolic treatment analogous to algebraic manipulations.

10. Mathematics as Postulational Thinking

The distinctive feature of a mathematical system lies in its assumptions. It has been explained above that a system of geometry is built out of a set of undefined concepts and undemonstrated propositions. That account of geometry may be adopted as an accurate model for founding and constructing any mathematical system. *A mathematical science consists of sequences of logical inferences originating in a set of definite presuppositions.* Such a logical tree reveals the essence of pure mathematics and tempts one to venture another definition of mathematics. *Mathematics comprises all logical investigations which concern the genesis and implications of consistent sets of postulates, together with the applications of the results thus obtained.* In other words, mathematics is the group of sciences which study the exact methods of drawing necessary conclusions from premises which are postulated and precisely stated.

The mathematical sciences are perfect examples of postulational or hypothetical thinking. Their assumptions, however, are not without an important kind of verification. Sometimes a postulate is less evident than the theorem which it proves, as the natural numbers are more readily understood than their logical presuppositions. Sometimes a great superstructure, such as Euclid's *Elements of Geometry,* is raised up before all its foundation stones have been explicitly laid down. The certainty, then, of a mathematical system does not depend solely upon a small set of postulates. Rather, the premises and the conclusions are mutually supporting. The consequences to which the postulates lead react to weaken or confirm those postulates. To this extent postulates function as hypotheses. If a group of postulates leads to nothing significant, it is promptly abandoned. The modern mathematician puts no exclusive or unshakable faith in the axiomatic character of his premises, but finds their justification in their power, fertility, and convenience in building non-contradictory and significant systems of thought.

A complete or ideal set of postulates, declares E. V. Huntington, *is "consistent, sufficient, and independent (or irreducible)."* [18] To make

[17] Russell, Bertrand, *Principles of Mathematics,* Cambridge University Press, pp. 5 and 429; *cf.* p. 436; *Introduction to Mathematical Philosophy,* London, Allen & Unwin, p. 25 and Ch. XVIII. Some deny this contention; see, for example, Boutroux, *op. cit.,* pp. 153–170.

[18] *Transactions of the American Mathematical Society,* April, 1902.

fully explicit the minimum essentials and to exclude completely the non-essentials is such a severe task that only a few of the greatest mathematicians have succeeded in it. Others unwittingly employ, sometimes, assumptions that are redundant, dependent, complex, or unformulated. Imperfect sets are adopted because they are more interesting, rapid, or convenient in development. Facility and fecundity in use may be preferred to brevity and simplicity in conception. In this way practical and esthetic motives may prevail over logical ideals. Compatibility alone remains as the indispensable property of postulate sets. The demands just indicated somewhat curb and guide the mathematical explorer in choosing from an embarrassing richness of possible postulates.

11. Analysis, Calculus, and Applied Mathematics

While the foundations of mathematics have been deepened and simplified by critical analysis, the special fields and superstructures have been enormously elaborated. No inventory of the amazing diversities of contemporary mathematics is possible here, except that mention may be made of that assemblage of studies called *analysis*. These studies deal with various mathematical facts which need intensive scrutiny from countless standpoints. Here belong analytic geometry, the problems of continuity and infinite series, functions in manifold variety, equations, probability, aggregates, and especially differential and integral calculus.

The aim of *calculus* is to determine precisely, that is, algebraically, the modes and laws of variations in changing systems. It represents the revolutionary step of reducing motion to exact calculation. "While the algebraic x is a fixed target, the x of calculus is a bird on the wing; x is a growing quantity." Ever-changing systems abound in life; for example, the covariation between heat and expansion in metals, air pressure and elevation, height and pressure in liquid containers, volume and diameter in a sphere. In the eleventh edition of the *Encyclopaedia Britannica* the notation of the infinitesimal calculus is employed in one hundred four articles (clock, lubrication, map, sky, steam engine, tide, etc.).[19] The creation of definite methods by which the infinite future states of perpetually changing systems may be rapidly and surely calculated is one of the grandest and most fascinating achievements of the human mind.

In *applied mathematics* empirical data and problems are introduced in a way that is foreign to pure mathematics, but mathematics is commonly regarded as a technical art as well as a pure science. The natural world honors our mathematical interpretations of it in a remarkable manner.

[19] Barton, S. G., "The Uses for Mathematics," *Science*, November 13, 1914, p. 698.

Tunnels, ships, shells, planets, go where we calculate they will go. The infinite applications of mathematics to the problems of real life give it an alluring and perennial interest. Many applications have been suggested above. Mathematical knowledge is indispensable in engineering and architecture, commercial and financial affairs. A great bridge is a mathematical miracle, and a noble cathedral is " petrified mathematics." Trigonometry is an essential instrument in sailing the seas, surveying the continents, and tracing the courses of the stars. Steamships, railroads, skyscrapers, insurance and banking enterprises, and the multifarious machines of industry are a few modern achievements which would be impossible without mathematics. In nearly all the sciences mathematics is a powerful tool of investigation. These facts are a few reasons for declaring that mathematics is one of the most important foundations of our material civilization.

12. Summary Characterization of Mathematics

The chief characteristics of mathematical reasoning may now be reviewed. Mathematical sciences are progressive creations of the human mind. The mathematician defines and elaborates an " apocalyptic vision of an infinite interior world." He carries generality and abstractness to the utmost height. " Mathematics is a hyper-world, a supersensuous world, the most stupendous and sublime of all fictions, yet a fiction which is true to reality, which matches reality at every point." [20] The creations of mathematics are real in the sense that they are conceivable and consistent.

By various devices the mathematician attains an unparalleled clearness, relevancy, and exactness in his thinking. He has no means of expressing vague ideas. He restricts his subject-matter to concepts and relationships which may be precisely determined. He seeks always to be explicit, and to be free from irrelevances, superfluities, and tacit assumptions.

Mathematicians have developed an exceedingly potent symbolism. Their abbreviations make for terseness of expression and rapidity in calculation. By the use of compact symbols and certain powerful methods, notably decimal notation and fractions, algebraic formulas, logarithms, and the infinitesimal calculus, problems may be solved in a few moments which otherwise would require days of labor and often could not be solved at all. Thus, by the use of logarithms, addition and subtraction take the place of multiplication and division, and with the slide-rule these operations can be performed almost at sight.

E. D. Roe, Jr., has strikingly illustrated the marvelous epitomizing power of mathematical symbolism by reference to a determinant of the sixteenth order which occupies two thirds of a page of large type. If this

were written out in full in the ordinary algebraic manner and printed in volumes of 200 pages, and if these books were placed in libraries of a million volumes each built 32 to the mile along both sides of an avenue, this determinant avenue would have to be a little more than 136 miles long to contain all the books.[20]

The mathematician has carried rigorous demonstration to a perfection that is proverbial. He pledges himself to this severe ideal: every step of thought is to be clearly stated and definitely supported by propositions previously admitted or proved. A. DeMorgan said: " It is easier to square the circle than to get round a mathematician."

Mathematics is notable also for the systematic form of its results. It contains some of the most precise and harmonious logical structures that human reason has produced.

Those who create the magnificent edifices of mathematics enjoy a sense of power and intellectual dominion. They have a delightful consciousness of mingled spontaneity and necessity. While their demonstrations are apodictic and undeniable, these demonstrations depend upon postulates which the thinker has freely chosen and may endlessly expand. In the ordered creation of number and form systems, in their symmetry and harmonious adjustment, the sensitive mind finds an elegance which arouses esthetic satisfaction. These systems embody an intellectual beauty, a " music of reason " (J. J. Sylvester), which lures one on to new explorations.

The following characterization of mathematics is from the pen of one who has a profound and affectionate appreciation of this ideal science. Bertrand Russell declares: " Mathematics, rightly viewed, possesses not only truth, but supreme beauty — a beauty cold and austere, like that of sculpture, without appeal to any part of our weaker nature, without the gorgeous trappings of painting or music, yet sublimely pure, and capable of a stern perfection such as only the greatest art can show. The true spirit of delight, the exaltation, the sense of being more than man, which is the touchstone of the highest excellence, is to be found in mathematics as surely as in poetry." [21]

We return to our original assertion that mathematics contains no peculiar kind of reasoning. It is like other thinking save that it carries to utopian excellence several fine qualities of scientific thought, notably clearness in conception, rigor in proof, and system in the formulation of results. Those who appreciate its achievements esteem it as the intellectual marvel of the world and mark it as a paragon for theoretical science. R. F. P.

20 *Scientific Monthly*, Vol. XVII (1923), p. 248.

21 Russell, Bertrand, " The Study of Mathematics," in *Philosophical Essays,* New York, Longmans, Green, 1910, p. 73; quoted with permission of the publishers.

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CHAPTER III

THE PHYSICAL SCIENCES

As the premises of mathematics are the postulates of pure thought, the building stones of natural science are perceived facts. To the risks of reasoning the natural scientist adds the hazards — the opportunities and marvels, too — of empirical observation. In proving and formulating his results, however, he emulates the impersonal precision of the mathematician. He employs his own exacting methods, which are rather well fixed and widely known. They will be illustrated in the following presentation of some of the fundamental concepts of natural science.

1. The Divisions of Natural Science

Every natural science is an intensive, experimental study of one of the many aspects of nature. *By physical nature is meant the space-time world, the totality of actual material events.* It is the realm of infinite and incessant activities. As a result of complicated mental processes, human beings come to perceive in this world such objects as animals, plants, mountains, seas, planets, and stars. By dividing all existing objects into living and non-living, there is gained a convenient principle for separating the natural sciences into two grand divisions: the physical sciences and the biological sciences.

We shall first review the physical sciences. They are four in number: astronomy, geology, physics, and chemistry. These overlap in many fields, as illustrated by astrophysics, biochemistry, physical chemistry, and geography. Each freely borrows from the others any methods or ideas which promise to be helpful.

A. ASTRONOMY

2. Hypotheses Concerning Planetary Motion

(*a*) *Early Views, especially of Ptolemy.* — *Astronomy is the science of the heavenly bodies, of the solar system, stars, and nebulae* (faint, cloud-like, self-luminous masses). The first major problem of the astronomer is: How do the planets of the solar system move? The progression of historical answers beautifully illustrates the use of working hypotheses in

science. The oldest cosmology of importance is the world-view of the Babylonians. They regarded the earth as the cubical and stationary center of the universe, surrounded by the seven spheres of the planetary divinities. It is noteworthy that the Chaldeans gave to the world the length of the year as 365¼ days, which is only eleven minutes too long.

Pythagoras (born between 580 and 570 B.C.) and all the later Greek philosophers held that the earth is spherical. Pythagoras and his disciples supported this view by the observation that as one sails towards Egypt, the stars which at first were barely visible near the southern horizon gradually ascend in the sky, while others in the north disappear. The Greeks noticed also that the shadow of the earth on a half-eclipsed moon is curved.

The geographer, Eratosthenes of Alexandria (276–195 B.C.), measured the diameter of the earth with remarkable exactness. He had learned that on the longest day in summer no shadow was cast at the bottom of a well at Syene (modern Assuan) on the Upper Nile. On the same day at Alexandria he noticed that the sun was little more than seven degrees from the zenith, or 1/50 of a circumference. The circumference of the earth, therefore, must be 50 times the linear distance between these two places. This distance was known, from comparatively accurate measurements of the Egyptian surveyors, to be about 5000 stadia. If we take Dreyer's estimate of a stadium as 517 feet, the earth would have a circumference of 24,500 miles, which is astonishingly near the truth. The result would be exact (namely, 24,860 miles) if the stadium were 525 feet. Because the same method of measurement is used today, Eratosthenes is regarded as the founder of geodesy; he has been called the "surveyor of the world."

The renowned system of Claudius Ptolemy (flourished 127–151 A.D. at Alexandria) shows the influence of Babylonian speculations. He believed that an immovable earth stood at the center of the revolving firmament because everywhere on the earth the stars appear, as Anaximander had suggested, to be of the same size, and to remain so. The earth, too, must be round, for lunar eclipses are seen earlier after sunset in countries to the west. He and others before him had observed that the planets, like the moon, move against the background of the stars, but that their speed is irregular. At times they travel noticeably faster than at others. The problem was how to interpret these variations in velocity to harmonize with the traditional view that only the perfect circle was a fitting course for the celestial divinities.

Ptolemy was able to explain these irregular orbits, and to preserve the venerable circle, by the ingenious device of Hipparchus, called an epicycle. An epicycle is a small rotating circle whose center moves along the

circumference of a larger circle. In Copernicus' day seventy-nine epicycles had become necessary, and the centers of many had been pushed to one side. The theory of Ptolemy agreed closely with observation. His greatest discrepancy amounted to about one third the angular diameter of the moon. For fourteen centuries his comprehensive work, *Almagest* (138 A.D.), was the bible of astronomy.

(*b*) *Copernicus.* — Nicolaus Copernicus (1473–1543), a Renaissance scholar who lived on the Baltic, shattered the geocentric hypothesis of Ptolemy as a result of a lifetime devoted to observation and mathematical labor. He begins by postulating that the universe and earth are spherical and that the motions of heavenly bodies are uniform circular motions, simple or compound. He proceeds then to show how the apparent movements of heavenly bodies "necessarily follow" from the rotation of the earth on its axis and the annual revolution of the earth around the stationary sun.

Copernicus also took the notable step of supposing that "the immovable sphere of the fixed stars" lies at an immense distance from the earth. He reasoned that since the earth moves, we should expect an apparent shift in the stars as the earth completes its orbit. His most careful observations failed to reveal any such shift. From this acknowledged fact he inferred that the stars are very far away. This shift is indeed so exceedingly small that it was not until 1830 that the Prussian astronomer, F. W. Bessel, discovered it. The angle made by the nearest stars when viewed from opposite sides of the earth's orbit is about the size of a five-cent piece at a distance of two miles.[1]

Although Copernicus failed to take the step from an eccentric circle to an ellipse, he reduced the epicycles from seventy-nine to thirty-four. The simplicity of his system was convincing, for why suppose that the countless multitudes of fixed stars describe the same regular daily motion about the earth, when the motion of the earth will explain all? The demonstration by Copernicus that the sun is the center of the solar system is known as the heliocentric theory. It has slowly wrought a revolution in human thought. He succeeded in shaking forever the hoary belief in the apparent stability of the earth. His achievement shows how untrustworthy sense appearances may be apart from the criticism and confirmation of reason.

(*c*) *Kepler.* — Epicycles were destroyed at one stroke by the simple elliptical law of John Kepler (German, 1571–1630). He became a friend of the indefatigable Danish astronomer, Tycho Brahe (1546–1601), who was famous for his marvelous new instruments and long-continued observations, especially of the motions of Mars. For twenty-two years Kepler studied the carefully recorded data of the celebrated Dane in a persistent

[1] Kullmer, C. J., Syracuse University.

endeavor to describe and predict planetary motions without sacrificing the idea of the time-honored circle. A discrepancy of a small fraction of a degree could not be explained away. Out of this discrepancy he resolved to build a new universe. He refused to doubt the unprecedented accuracy of the observations of Tycho Brahe. He freed himself from the dogma of the circle by venturing to choose from all geometrical forms which exist the one that best harmonizes the facts.

Kepler finally discovered that if he assumed elliptical orbits, he could eliminate every troublesome epicycle. He was elated to find that he could precisely describe planetary motions in three simple laws. His accomplishment illustrates how fruitful may be the union of skilful observation with a "volcanic imagination" and mathematical rigor. He not only proved that his laws account for all observed facts, but that all proposed alternatives, nineteen in number, leave outstanding errors that cannot be due to malobservation. His first two laws were published in 1609; the third, in 1619:

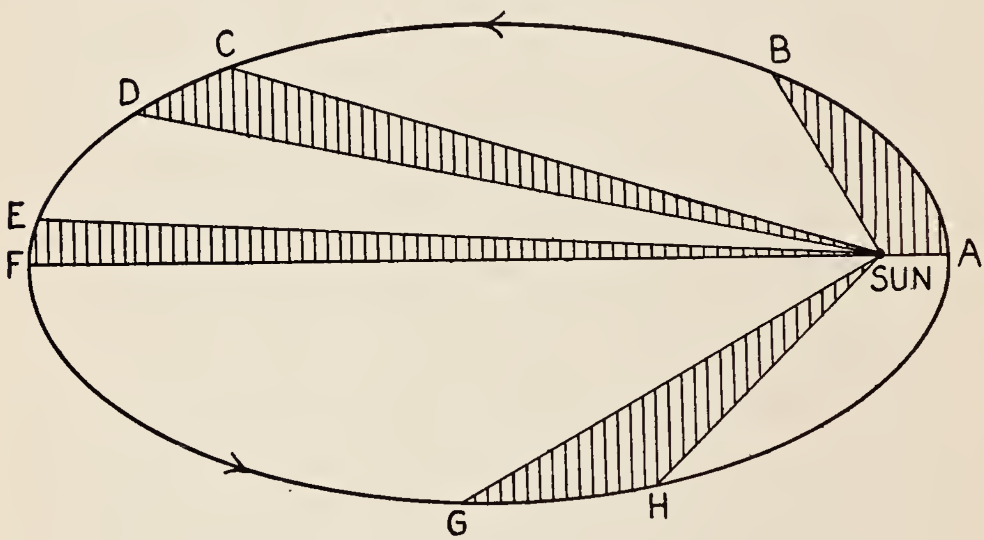

FIG. 1. THE LAW OF EQUAL AREAS

The shaded areas are meant to be equal. A planet travels the different arcs, *AB, CD, EF* and *GH,* in equal times. It moves fastest when nearest the sun. (The ellipse is greatly exaggerated for illustrative purposes.)

1. Each planet moves in an ellipse which has the sun at one focus (elliptical law).
2. The straight line joining the planet and the sun sweeps out equal areas in equal times. This law of areas is illustrated in Figure 1.
3. The squares of the periodic times (T^2) are proportional to the cubes of their mean distances (D^3) from the sun (harmonic law). For example, earth's T^2 : Neptune's T^2 :: earth's D^3 : Neptune's D^3.

In the same year, 1609, Galileo Galilei (Italian, 1564–1642) heard that a Dutchman had discovered how to combine lenses in such a way as to make distant objects look large. He proceeded to re-invent the telescope and to amaze the world with a rapid succession of discoveries which strongly confirmed the Copernican theory. Most startling was his discovery that four moons revolve about Jupiter. Most important was his discovery that Venus, as it revolves about the sun, shows the same phases as we observe in our moon. This was an indubitable proof of the heliocentric hypothesis of Copernicus. His formulation of the laws of falling bodies prepared the way for the innovations of Newton.

(*d*) *Newton.* — Sir Isaac Newton (English, 1642–1727) took the next great step in astronomy by formulating the *law of gravitation.* This law declares that *every particle of matter in the universe attracts every other particle with a force which varies directly as the product of their masses and inversely as the square of the distance between them.* Newton showed how the laws of Kepler and Galileo were mathematical consequences of this single grand conception. This law applied to falling bricks and projectiles, to swinging comets and remote stars. He first conceived it in 1665 at the age of twenty-three, when, he says, "I was in the prime of my age of invention." It was his answer to the question: Since bodies on high mountains fall, as elsewhere, toward the center of the earth, should not bodies remote from the earth, the moon for example, show a like tendency?

He undertook to test his hypothesis by a study of lunar motions. He knew, correctly, that the distance of the moon is sixty times the radius of the earth. If his hypothesis were true, it would follow that the moon is deflected from motion in a straight line, that is, falls towards the earth, $1/60^2$ of the distance which a body falls in a second on the surface of the earth. The latter distance is 193 inches, and $1/60^2$ of it is 0.0535 inches. A recent calculation makes the deflection of the moon 0.534. Newton calculated the deflection to be 0.044 inches on the mistaken assumption that a degree is 60 miles long. This result showed such a discrepancy with his prediction that, in truly scientific spirit, he abandoned his theory in favor of the supposed facts of observation. In 1671, six years later, Newton learned that Picard in France had corrected the circumference of the earth and found a degree to be 69 miles instead of 60. Newton started to repeat the calculations, but was too excited to finish them. A friend completed them for him and the result showed a close agreement with the predicted one. Newton enthusiastically took up again the demonstration of his great law of gravitation. During a century and a quarter mountains of evidence have accumulated to support Newton's law. Only the irregularities of Mercury's motion remained unexplained until Einstein recently formulated a new and more exact law of gravitation.

Newton has shaped the methodological ideals of modern scientists probably more than any other thinker. Above all, he combined mathematical interpretation with empirical observation. His marvelous success in displaying the laws of moving bodies stimulated the search for order in all physical processes. Under his influence scientists came to regard the world as a vast orderly machine. This postulate of mechanism has prevailed in natural science to the present time. The business of the scientist is to describe natural phenomena in brief and general laws and express them whenever possible in mathematical formulas.

3. Revelations of Telescope and Spectroscope

The solar system constitutes one set of astronomical problems. The other group is presented by the stars and nebulae beyond. The solution of these problems is dependent upon the perfection of many delicate instruments of observation. By reference to the three most important instruments the history of astronomy may be divided into three periods as follows:

1. The time before the invention of the telescope.
2. From the invention of the telescope to the invention of the spectroscope.
3. The period in which the spectroscope and the camera have been employed.

Other necessary instruments are constructed for precisely measuring intervals of space and time. The clock or chronometer is almost as important as the telescope.

Amazing revelations have come with every increase in the power of the telescope. In the *whole* heavens about 5000 stars are visible to the average unaided eye. In a 2½-inch telescope F. W. A. Argelander (Prussian, 1799–1875) charted 324,000 stars and covered only slightly more than half the sky. In the Yerkes 40-inch telescope (completed in 1896; near Lake Geneva, Wisconsin) probably 100,000,000 stars are visible. Through the largest telescope in the world, in the Mt. Wilson Observatory near Pasadena (completed in 1917; aperture, 100.4 inches; weight of mirror, 9000 lbs.) considerably more than a billion stars would impress photographic plates of long exposure. Statistical classifications of the stars show a proportional decrease in numbers among the fainter magnitudes. From this fact it is estimated that the total number of stars is of the order of 30 or 40 billions.[2]

[2] Duncan, J. C., *Astronomy,* New York, Harper, 1926 (one of the best textbooks), pp. 294–297.

A glance at any photograph of the Milky Way leaves no doubt about the difficulty of enumerating the stars. The Milky Way contains perhaps 47,000,000 stars.[3] In its brightest regions, "the stars pile up in great cumulous masses like summer clouds." It is estimated that 95 per cent of the soft nocturnal light that brightens it comes from stars which cannot be seen with the naked eye. The fact that we see remote stars at all proves that they radiate enormous quantities of light, since the intensity of light varies inversely as the square of the distance from the source.

In the older astronomy the instruments used concerned chiefly the direction of light. In the new astrophysics special instruments have been devised for investigating light with respect to wave length, radiation pressure, intensity, polarization, and other properties. The most important of these instruments is the spectroscope. Kirchhof and Bunsen began in 1859 and 1860 to interpret what this wonderful instrument had to disclose concerning the sun and stars. It has led to many unexpected and marvelous discoveries. It is the microscope of astronomy.

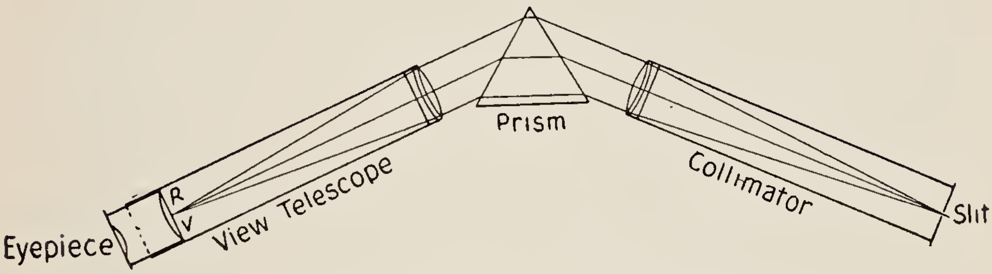

Fig. 2. The Principal Parts of a Prism Spectroscope

The spectroscope is an instrument which produces in the laboratory an artificial rainbow which man may observe at will. It consists of three parts, the collimator, the dispersion piece (prism or grating), and the view-telescope or camera (see Figure 2). A small beam of light is made to enter the collimator through a narrow slit at one end; it passes out through an object-glass at the other. The parallel light then falls on the dispersion piece, which bends the rays of different wave lengths in slightly different directions. The telescope focuses and magnifies these bundles of light as line images across a band of merging colors known as the spectrum (see Figures 3 and 4). A comparison spectrum is often put on one or both sides of a spectrum under investigation. It consists of sharp, strong lines produced by light of known character. In astronomical work the spectroscope is ordinarily attached to a telescope.

[3] Russell, Dugan, and Stewart, *Astronomy,* Boston, Ginn, 1926–1927 (a complete and masterful work in two volumes), p. 651.

Space permits only a brief indication of the dozen or more facts about the sun and stars which we would not know without the spectroscope. First of all, by its means the chemical composition of sun and stars is analyzed. If a compound of lithium is inserted in the flame of a Bunsen burner, the flame becomes strongly red and produces in a spectrum a single brilliant carmine line. Similarly, incandescent sodium yields two yellow images close together. Iron has two thousand lines in the visible spectrum. Each element has lines which, so far as known, are all different from those of every other element. The distinctive lines of most chemical elements have been experimentally charted. This knowledge may be deductively applied to determine the constitution of the heavenly bodies. In Figure 4 may be seen several coincidences of stellar titanium lines with those in the comparison spectrum. The same elements for the most part are abundant in the stars and sun as on the earth: silicon, sodium, magnesium, calcium, aluminum, and iron.

Spectra are divided into bright-line, continuous, and dark-line or absorption spectra. The solar spectrum consists of dark lines, called Fraunhofer lines, which are seen against a background of light (see Figure 3). These dark lines are due to the fact that incandescent vapor absorbs or cancels all radiations of its own wave length which pass through it, if they come from a hotter source. The dark lines occupy precisely the positions of bright lines in bright-line spectra. The dark lines in the solar spectrum, therefore, indicate the elements that are present in the envelope of the sun. Rowland's celebrated map of the solar spectrum was about forty feet long and contained twenty thousand lines. Forty-nine elements have been identified with certainty on the sun. In 1868 helium was discovered spectroscopically on the sun before Ramsay found it on the earth in 1895.

It has been found that certain lines are greatly strengthened as the temperature of a luminous source increases. Half a dozen temperature classes of spectra have been determined, and the surface temperatures of various stars have been calculated. These temperatures range from 3700° C. to 35,000° C.[4] The stellar interiors are undoubtedly many times hotter than this. While the surface temperature of the sun is more than 6000°, Eddington thinks that its temperature in the center may be 40,000,000°.[5] The statistical studies of Kapteyn show that the average mass per star throughout the universe is 1.6 times that of the sun.

Other spectroscopic effects or variations have been correlated with definite physical conditions in the sources of light. Among these are the pressure shift toward the red resulting from high pressures, and the splitting

[4] *Op. cit.*, pp. 735 and 868.

[5] Eddington, A. S., *Stars and Atoms*, New Haven, Yale University Press, 1927, p. 14.

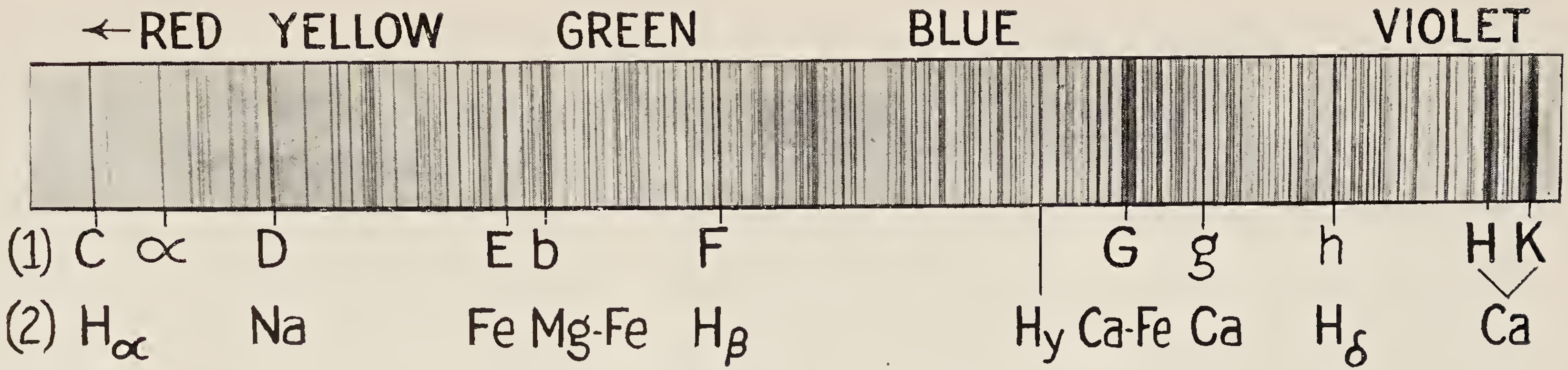

FIG. 3. THE VISUAL SOLAR SPECTRUM

As seen in a prismatic spectroscope of low dispersion. The extreme red portion is not included; it contains stray lines due to the earth's atmosphere. The most conspicuous lines in the spectrum are marked in line (1) by their Fraunhofer letters. The Greek letter alpha between C and D is the head of the band of atmospheric oxygen. In line (2) distinctive lines of the following chemical elements are indicated: hydrogen (α, H_β H_γ, and H_δ.), sodium (Na), iron (Fe), magnesium (Mg), and calcium (Ca). (After G. Müller.)

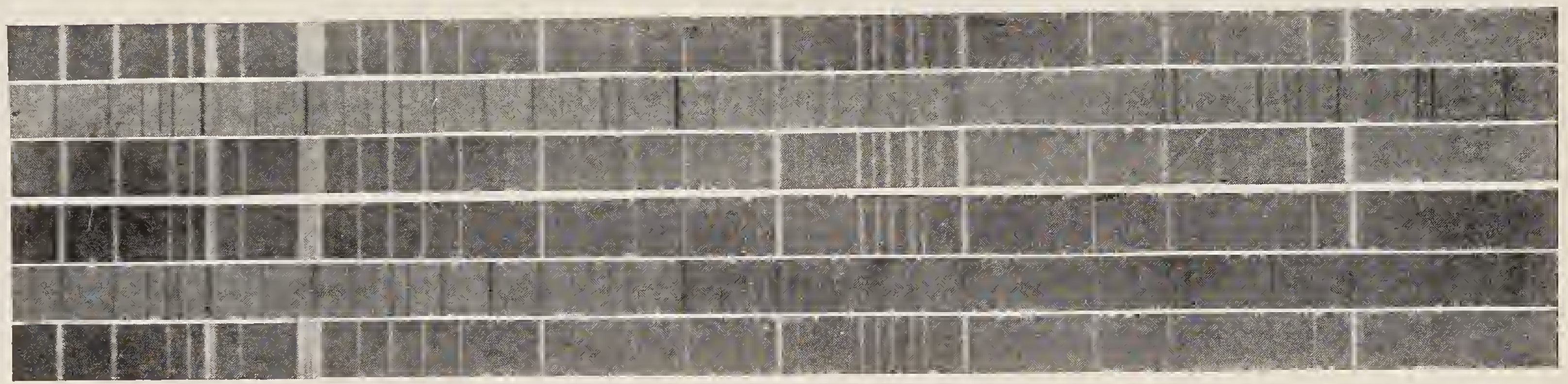

FIG. 4. THE SPECTROSCOPIC BINARY *MU ORIONIS*

The middle band in each of the two spectra is a comparison spectrum of titanium. Several of its lines closely coincide with the spectrum of the star on either side. (Discovered and photographed at Yerkes Observatory.)

1908

1915

1920

Fig. 5. Photographs of the Binary Star Krueger 60.

Taken in three different years by Barnard with the Yerkes forty-inch telescope.

up of spectrum lines by powerful magnetic fields, notably by sunspots (Zeeman effect).

Perhaps the most wonderful achievement of spectroscopy is the determination of the velocity of the stars to and from the earth. Comte and others declared that this wonder was impossible. It is made possible by the remarkable discovery that a slight shift occurs in a spectrum when the distance is uniformly changing between a source of radiation and the instrument. A movement toward the earth is indicated by a shift toward the violet end; a shift toward the red means recession. The latter shift is well illustrated in Figure 4. This effect is profitably tested by comparing two spectra from opposite sides of the sun and checking the results against those obtained by following the movement of sunspots. The sun itself is moving through space at the rate of 12½ miles per second. The speed of the earth in its orbit is 18½. Velocities from 6 to 18 miles per second are very common among the 3000 stars already measured. Sixty miles is uncommon, while the greatest speed known is 240 for the variable star R Z Lyrae.

4. The Magnitude and Unity of the Cosmos

The grandeur of the universe which man imagines far excels the stellar glories which he perceives. The vast conception which he has constructed is derived solely from the faint beams of light which through immense ages gradually reach our tiny earth. Out of these beams he reads, by the aid of his sensitive and versatile instruments, the amazing secrets of the stars. As he perfects his instruments and gains finer technical and logical skill, he discovers new wonders and vaster magnitudes.

In recent years man's conception of the size of the universe has immensely enlarged. We know that most of the stars which are ordinarily visible are concentrated in the luminous belt of the Milky Way or Galaxy. In order to have a convenient unit for measuring distance the astronomer commonly uses the light year, the distance which light travels in one year, namely 5,880,000,000,000 miles. The nearest known star, Alpha Centauri, below the southern horizon, is 4.3 light years away from the earth; in other words, it is 275,000 times as far away as the sun. It takes light forty years to come to us from the North Star. The five Dipper Stars are seventy to eighty light years away. Most visible stars lie at distances of 325 light years or more. Our watch-shaped Milky Way or Galaxy, according to Hale, is about 300,000 light years in diameter. One of the largest of its stars, the red Betelgeuse in the right shoulder of Orion, is 210 light years away and has a volume at least 27,000,000 times that of our sun. Our sun is one hundred times the diameter of the

earth, ten thousand times its area, and more than one million times its volume. Betelgeuse, however, has a mass which is only about thirty-five times that of our sun; its density, therefore, is far less than that of our atmosphere.

Our Galaxy is only one among multitudes. The huge telescopes of modern times reveal hazy, partly luminous nebulae and star systems at almost inconceivable distances beyond our Milky Way or Galaxy. Since they are independent of one another, they have been called island universes, and are comparable in size with our Galaxy. These nebulae have various shapes, but spirals are by far the most numerous. The very beautiful spiral in Andromeda is shown in the frontispiece of this book.[6] Curtis found three hundred nebulae on a single photographic plate. Frost believes that more than a million spirals are visible in a large telescope.[7] When we consider that every one of these is an island universe made up of millions of stars like our own Galaxy, the awful magnitude of the firmament may dimly appear before our imagination.

These nebulae beyond our Galaxy are so distant that it takes light from them one to ten million years to reach us, and some of the fainter clusters are probably much more remote. Hubble recently estimated that the most distant objects visible in the largest telescope are about 140 million light years away.[8] This is man's farthest reach into the depths of the universe. We do not wonder that Ernst Haeckel years ago referred to " our mother earth as a mere speck in a sunbeam of illimitable space."

In spite of the immensity of the cosmos, there are good reasons for supposing that it possesses a measure of unity. We have seen how celestial objects everywhere exhibit a striking uniformity in chemical composition. Hydrogen, iron, and other elements are universally found in the most widely separated regions of the heavens. Many stars revolve around each other as the earth revolves around the sun; they are called double or binary stars, and are very numerous. In Figure 4 the star lines in the lower spectrum are slightly displaced toward the left or red; in the upper, taken on a different date, there is a larger displacement in the same direction. These shifts are due to the movement of the stars away from the earth in the line of sight, at the rate of twelve miles per second in the lower spectrum and thirty-nine in the upper. This variable speed is due to the fact that this star and an invisible companion are revolving about a common center of gravity in a period of 4.45 days, at the same time

[6] *Cf.* Russell, Dugan, and Stewart, *op. cit.*, pp. 843–858.

[7] Frost, E. B., " The Structure of the Cosmos," Ch. IV in *Contributions of Science to Religion* (S. Matthews, editor), New York, Appleton, 1927.

[8] *Scientific American*, February, 1927, p. 123. *Cf.* Russell, H. N., " Has the Universe a Limit? " *Scientific American*, February, 1928.

that the pair are receding from us at a speed of twenty-eight miles per second. Thus, the same laws of motion prevail in remote stellar groups as in our own solar system.

The three photographs of the binary star in Figure 5 show conspicuous orbital motion in the course of twelve years. These stars are faint dwarfs which are visible only in the telescope. They are at a distance of twelve light years. They turn about each other once in fifty-five years. In size, their orbit is about half way between the orbits of Mars and Jupiter. It is notable that in the course of twelve years the pair has moved away appreciably from the lower star at the right. This and a hundred other binaries whose orbits have been studied conform to the laws of Kepler.

5. The Evolution of the Stars and Solar System

Astronomers are striving at the present time to apply the concept of evolution to the "eternal stars." Although the results remain tentative, they are exceedingly interesting. The immense ages involved in stellar evolution make changes imperceptible in the moment of our brief human lifetime. But perhaps the stars are like a bed of mushrooms: if we can see the latter for only a second, we may perceive or photograph plants at every stage of evolution. Perhaps every visible step of development and decay could be found among the stars if only we knew the law that governs these changes.

That the stars undergo orderly transformations is suggested by the great differences among them in color, size, brightness, temperature, etc., and also by their reckless radiation of light and heat. Some stars are much more diffuse than the air we breathe, while the companion of Sirius has fifty thousand times the density of water. If a pint of matter could be brought from Sirius to the earth, it would weigh twenty-five tons. Some stars are ten thousand times brighter than the sun, while the sun is ten thousand times brighter than the faintest star.[9] It is noticeable also, as Sir N. Lockyer has shown, that on the hottest stars only the lightest and simplest elements, notably hydrogen and helium, are found. As the temperature decreases, heavier elements and more complex substances appear.

The origin of the stars may remain a mystery until the source of their tremendous energies is known. When we see them first they are, of course, already stars. In their first stage they are very diffuse red globes of gas with a surface temperature of little more than 3000° C. As they radiate

[9] Payne, Cecilia H., "Stellar Evolution," *Scientific Monthly*, Vol. XXII, 1926, pp. 419–423. *Cf.* Jeans, J. H., "The Wider Aspects of Cosmogony," *Scientific Monthly*, May, 1928, pp. 454–463.

energy, they seem to contract and grow hotter. In middle age, therefore, they are dense and very hot, their temperature ranging from 15,000° to 35,000°; they are first blue-white in color and then yellow. In old age they grow cool again, and become smaller, denser, and swifter; they are first orange, then faint deep red.

The stars, then, begin as super-giants and end as relative dwarfs. Originally three hundred times the mass of the sun, they may decline until they become one quarter of its mass. The red dwarfs probably continue to cool, and, after immense periods of time, become invisible. Cecilia H. Payne estimates that this evolution takes 10^{15} (1 with 15 zeros) years, and calls it " the longest and most solemn process known to man." [9]

Our sun belongs to the class of yellow dwarfs. Through long ages, compared with which our earth is very young, it has been discharging into space tremendous quantities of energy. Nevertheless, Russell, Dugan, and Stewart calculate that it would take about five trillion years " for the sun to diminish to its existing mass from twice that value. To shrink to half its present mass would require forty trillion years more." [10] This hypothesis that mass may be transformed into energy is one of the most revolutionary conceptions of recent years. If the sun loses by radiation 1/15,000 of its mass in a billion years, it is likely to shine on for thousands of billions of years in the future. In the year 19,000,029 the climate of the earth will be considerably colder and the year a little longer, but man, with his accumulated stores of wisdom, will undoubtedly be able to survive amid strange and satisfying comforts, provided no unexpected cosmic catastrophe overtake him.

It has long been supposed that our solar system is indeed a system, that its parts had a common origin in some primordial nebula. This is indicated by the facts that all members of this system are advancing through interstellar space with the same rapid motion and that the nearest star is ten thousand times as distant as Neptune, the remotest planet in our solar system. In the attempt to explain the origin of the solar system Kant proposed in 1754 and 1755 the so-called nebular hypothesis. This was greatly elaborated in 1796 by P. S. Laplace (French, 1749–1827) and prevailed throughout the nineteenth century. According to this view, as the whirling sun, hot and gaseous, contracted as a result of cooling, it revolved faster and faster, and occasionally threw off rings of gases. These gradually condensed into rotating spheroids, and became planets through a cooling process. In the meantime they also had thrown off rings, which cooled to form their satellites.

In spite of the beautiful simplicity of the nebular hypothesis, it has

[10] Russell, Dugan, and Stewart, *op. cit.*, pp. 591 and 919. Courtesy of Ginn & Co.

now been entirely abandoned for many reasons.[11] It has been shown, for example, that only separate molecules and not gaseous masses could fly off the sun. Further, according to the law that a shrinking sphere increases in rotation, the sun should now be turning 270 miles a second; actually it maintains a leisurely pace of 1 1/3 miles. Also, if the Laplacian hypothesis were true, a planet should rotate faster than the revolutions of its moons. As a matter of fact, Phobos, the moon of Mars, travels three times around Mars while Mars rotates once.

In 1900 Chamberlin and Moulton of the University of Chicago advanced the planetesimal hypothesis. A form of this conception, called the tidal theory or the hypothesis of dynamic encounter, is now commonly regarded as the best explanation.[11] Although it is not free from difficulties, it best harmonizes the known facts and laws. The hypothesis assumes that during inconceivably long epochs of time our sun existed in a great void as a solitary island, without planets or other companions. It was a gigantic, seething mass of glowing gases, torn by violent storms which hurled up fountains of fire, sometimes as high as 500,000 miles, a distance greater than its own radius. It is furthermore supposed that, perhaps five or ten billion years ago, a very rare cosmic catastrophe occurred: another star chanced to pass relatively close to the sun without colliding with it. The gravitational attraction of the visitor, combined with the expansive tendencies of the solar gases, raised monstrous tides of matter from the sun. These amounted to perhaps 1/700 of its total mass. The roving star imparted a crosswise motion to the detached clouds, and as it moved away, they were left revolving around the parent sun in elliptical orbits.

The vaporous substance thus drawn off cooled and contracted to form countless bodies called planetesimals. These bodies varied enormously in size, ranging from stray molecules of gas to huge knots of matter. The latter became nuclei for the planets and their satellites. Varying guesses put the original mass of the earth from one third to one tenth its present size. Some suppose that the gaseous earth liquefied and solidified very rapidly, perhaps in fifteen thousand years. With the formation of a permanent surface, geologic history began.

B. GEOLOGY AND GEOGRAPHY

6. Definition and Division of the Earth Sciences

We turn now from the dizzy immensities of the stellar universe to the fascinating story of our mother earth. Here also we perceive orderly

11 *Cf.* Chamberlin, R. T., "The Origin and Early Stages of the Earth," Ch. 2 in *The Nature of the World and of Man* (physical and biological sciences; Newman, editor), University of Chicago Press, 1926.

changes advancing through vast ages of time. The diverse studies of the earth make up two extensive groups of sciences, geology and geography. Geology is concerned primarily with the history of the earth, and especially with its crust. It may be defined as *the science of the origin, evolution, and constitution* (*materials, forces, structures*) *of the earth as recorded in the rocks.* It seeks to describe the nature and changes of the earth from its earliest appearance as a planet to the present time, and from its center to the limits of the atmosphere.

Geography is a comprehensive synthetic science. It is a thorough investigation of how land forms, soils, bodies of water, climates, ocean streams, etc., affect the life of plants and animals, and, above all, the races and nations of men. Geography may be defined as a *systematic description of the effects of the surface features of the earth upon the distribution and behavior of mobile objects upon it.* Geography has been called the geology of the present as geology has been called the geography of the past. The geographer, even more than the geologist, freely appropriates knowledge from many other sciences. He borrows chiefly from geology, physics, biology, ethnography, and history. The scope of the earth sciences is indicated by the following outline of their problems:

A. GEOLOGY:

1. The study of the material composition of the earth (rarely called *geognosy*); these constituents are commonly divided into three spheres, with corresponding sciences:
   a. The atmosphere: *meteorology.*
   b. The hydrosphere: *hydrognosy.*
   c. The lithosphere — all the solid substance of the earth — studied by:
      1′. *Mineralogy,* the science of minerals.
      2′. *Petrology,* the science of rocks.

2. *Dynamic geology* treats of the agencies which produce changes in the earth; these agencies may be grouped under three dominant processes:
   a. Vulcanism: movements of lava, geysers, thermal springs, and other results of igneous agencies.
   b. Diastrophism: all movements of the lithosphere; for example, the elevation and subsidence of land, faulting, and earthquakes. These movements depend mainly upon gravity, but in part also upon heat and chemical action.
   c. Gradation includes all surface processes (erosion, transportation, deposition, etc.) which level land down or up:
      1′. Atmospheric agencies: changes in temperature or wind, resulting from the unequal distribution of solar energy;

2′. Hydric and glacic forces: rainfall, running water, lakes, oceans (waves, tides, currents), snow, and ice;
3′. Biotic agencies: plants and animals, *e.g.* earthworms and ants.

3. *Structural* or *geotectonic geology,* a study of the architecture of the earth in the light of all other branches: general structure of the earth, kinds and arrangements of rocks, ore deposits, continents, mountains, plains, etc.
4. *Physiography,* or physical geography, the geology of the present time; an explanation of actual surface features of the earth; it depends upon both dynamic and structural geology.
5. *Historical geology;* all other branches contribute to this one. It is an attempt to determine the chronology of the earth's development; it includes:
   a. *Cosmic geology,* a study of the evidence concerning the origin, forms, motions, and materials of the earth before the appearance of life.
   b. *Paleontology* (also a division of biology), a study of the development of life on the globe, especially as found in fossils.
   c. *Paleogeography,* the physiographies of the past, a systematic description of the development of land and water bodies and of climates through successive periods.
6. *Economic geology:* mining, engineering, and petroleum geology.

B. GEOGRAPHY:

1. *Mathematical geography:*
   a. *Geodesy* deals with the dimensions of the globe and with areas and positions on it.
   b. *Topography* provides detailed descriptions (configuration, relief, elevations) of particular spaces.
   c. *Cartography,* the art of making maps.
2. *Physical geography:*
   a. Of land: *physiography.*
   b. Of water: *hydrography* (including *oceanography*).
   c. Of the atmosphere: *climatology.*
3. *Biogeography:*
   a. *Phytogeography,* geography of plants.
   b. *Zoogeography,* geography of animals.
   c. *Anthropogeography or human geography* (including *commercial* and *political geography*).
4. *Historical geography: paleogeography.*

7. The Early Stages of the Earth

We shall now set forth some basic concepts and methods of historical and dynamic geology. A leading and fascinating problem concerns the

primitive stages of the earth. Its history, according to Chamberlin and Salisbury,[12] may be divided conveniently into three overlapping eons. A dominant process distinguishes each of these periods. (1) In the *formative eon* planetesimals consolidated to build up the material of the earth. (2) The *extrusive eon* was notable for its gigantic volcanic activity. Then (3) came the wear and slow transformations of the *gradational eon.* All three of these processes are still going on, the first two to a small extent, gradation as much as ever.

The study of the formative period must be indirect, since no geologist has consciously seen any of the primeval crust of the earth. We described above how the earth perhaps was born of a solar tide in consequence of an extraordinary encounter with a visiting star. As the infant planet swept on in its orbit it gathered into itself, very rapidly at first, great quantities of planetesimals. It is still slowly increasing in mass as a result of the millions of planetesimals, commonly called meteors, with which it collides every day.

At the outset, the earth, because of its relatively small mass, probably could hold only a thin layer of gases, which consisted chiefly of water vapor. At first there was no free oxygen; the first oxidized or red rocks appear in the Proterozoic era (for this and other eras see Table I, page 48). An atmosphere has gradually accumulated from the ingathering of planetesimal molecules and especially from the emissions of volcanoes and thermal springs.

The present relative abundance of elements in a ten-mile crust has been estimated by F. W. Clarke. Three fourths of this stuff consists of oxygen (50.02%) and silicon (25.80%). 22.37% is made up of seven other elements which are, in order of abundance, aluminum, iron, calcium, sodium, potassium, magnesium, and hydrogen. The remaining 1.81% is composed of very small quantities of the other chemical elements. Up to date mineralogists have analyzed chemically about 8600 minerals.

Prodigious volcanic activity characterized the second stage in the history of the earth. Widespread deformation of the earth's crust and the predominance of igneous and metamorphic rocks in the lithosphere are silent witnesses to the mighty engines of heat and gravity which have operated at many different times through the ages.

Opinions vary as to the sources of the tremendous heat which volcanic activities manifest. The interior compression resulting from the increasing mass of the earth probably has produced much of it. It is now known that the interior of the earth, although very hot, is not molten or liquid. The earth behaves like a solid elastic body with the rigidity of tool steel. This

[12] Chamberlin, T. C., and Salisbury, R. D., *A College Textbook of Geology,* New York, Holt, 1927, p. 435.

fact is proved by the way earthquake vibrations are transmitted, and by the tides or deformations made by the moon in the solid body of the earth. Perhaps the chief causes for periodic volcanic upheavals are the enormous accumulations of heat resulting from the spontaneous decomposition of radioactive substances which are widely distributed in the crust of the earth.

At an unknown place — perhaps at several places — and at an unknown time the first living cells appeared on the earth. The best current estimate as to the time when life began places it at a period about a billion years ago. No life, of course, existed in the formative eon. Some suppose that life dawned some time during the Archeozoic period. In the Proterozoic era a few fossil remains furnish direct evidence of life. The indirect evidence is abundant in the form of great beds of limestone, iron, and black slate.

The first tiny organisms probably lived their evanescent lives in the warm waters along the shores of ponds or shallow seas. New, larger, and more enduring forms very gradually developed in the hard struggle for existence. Then the mighty forces of the gradational eon ground down the surface rocks of the continents and deposited soil here and there. Through other long ages little plants increased in size and spread slowly over the land to paint green for the first time the gray and barren faces of the lifeless continents. The rocks of the early Paleozoic era show some remains of land plants; at that time the low-lying hills may have been green. In the meantime minute animals had appeared in the seas, and in the course of time these too increased in size and some of them ventured farther and farther from their watery birthplace.

We shall not endeavor to trace in detail the story of organic evolution. The epochs in earth history are marked by the appearance or predominance of distinctive types of life, as indicated in Table I. The Archeozoic and Proterozoic eras together are commonly called pre-Cambrian. They are followed by the better known eras of ancient, medieval, modern, and recent life. The five percentages are the estimates of Chamberlin and Salisbury concerning the relative extent of the eras in question. The eras are only the grand divisions of geological time, the volumes in the book of terrestrial history. As the result of specialized studies these eras have been subdivided extensively into periods, periods into epochs, and so forth.

In Table I only the major characteristic events of the great eras can be indicated. Between the eras revolutionary physical changes took place, and these cannot be included in the space available; double lines mark the epochs of the three greatest of these revolutions. The time periods have only a measure of relative exactness. Obviously, the space relations in this chart are not relative. If the Christian era were represented by an inch of

Table I. The Subdivisions of Geologic Time

ESTIMATED YEARS B.C.		ERAS	DOMINANT LIFE	MAJOR PHYSICAL EVENTS
10^5	GEOLOGIC TIME	6. Psychozoic or Quaternary (reign of mind)	*Pithecanthropus erectus* (Java ape-man)	Last great age of ice Old Stone Age begins
		5. Cenozoic or Tertiary (modern life; 4%)	Modern forms of plant life Age of Mammals and Flowering Plants	Erosion of mountains
10^6 10^7			Man-ape changing into man Higher mammals and primates Birds (toothless)	Andes, Himalayas, Alps, Rockies, Pyrenees, and others, made or rejuvenated
$10^7 \times 6$ 10^8		4. Mesozoic (medieval life; 11%)	Reptiles (*e.g.* dinosaurs and flying reptiles) Rise of birds with teeth, flowering plants, and higher insects Higher forms of shell fish	Extensive continent making continued; Sierra Nevada Mts. thrown up
$10^8 \times 3$		3. Paleozoic (ancient life; 30%)	Beginning of vertebrates First insects and land vertebrates Amphibians and Primitive Floras (coal floras) Rise of Fishes and Invertebrates (*e.g.* brachiopods)	Emergence of continents; mountain making (Appalachians) Varied climates 60% of North America submerged Extensive marine deposits
$10^8 \times 6$		2. Proterozoic (earlier life; 25%)	Abundant life of unknown forms; rare fossils of primitive invertebrates (*e.g.* worms)	Earliest known glaciation; extensive sedimentation; great ore deposits, espec. iron
10^9		1. Archeozoic (primeval life; 30%)	No fossil evidence of life Probable dawn of unicellular life	Beginning of gradation and sedimentation; extensive volcanic activity and mountain making
	ASTRONOMIC TIME	Formation of planets	No life	Growth of the earth and other planets by infalling planetesimals. Atmosphere and oceans develop.
10^{10}		Time of solar nebula	No life	A star passing near our sun drew off masses (planetesimals) from it and set them in revolution.
		Time of spiral nebulae	No life	Rotating spiral nebulae perhaps were throwing off masses which formed galaxies of stars.

space, the beginning of the Archeozoic era, one billion years ago, would have to be eight miles away. On a scale of one minute for the Christian era this vast age would be ten years long.

8. The Age of the Earth

Many attempts have been made to answer the riddle: How old is the earth? Estimates have steadily mounted through the centuries. For two hundred years the Christian world was bound by the unsubstantiated guess of Bishop Ussher who, in 1650, fixed the date of the creation of the earth as 4004 B.C. At the end of the nineteenth century the conservative geologists held to 20,000,000 years. In 1908, 100,000,000 years was generally accepted as a fair estimate. J. W. Gregory asserted in 1922 that " 1,000,000,000 is a moderate minimum," while H. N. Russell in 1921 estimated the age between two and eight billion years.

Many interesting methods have been used for calculating the age of the earth. One method consists in calculating how long it has taken to build up the seventy or eighty miles of different sedimentary strata that are now exposed in various regions of the world. If a foot of sediment is laid down on an average in every 880 years, sedimentation must have begun more than 300,000,000 years ago.[13] The youthful Colorado River offers a fascinating opportunity to study the story of the earth's crust. It has cut a gorge a mile deep. The upper half of the canyon consists of sedimentary rocks which were laid down by a shallow sea. Underneath these are clear evidences of a plain which had been worn down long before by ages of weathering. " Below these level strata, the river has eroded another half-mile or so through tilted sedimentary rocks. Below these it has entered a crystalline rock without stratification. There is an irregular contact between the upper level strata and the lower tilted strata, and another between the tilted strata and the crystalline rock at the bottom of the great gorge." Bretz estimates that this lowest " peneplanation was completed probably more than 700,000,000 years ago." [13]

The most reliable and refined timekeepers of the ages are radioactive substances. More than thirty of these are distributed throughout the earth's crust. The two most important ones are uranium and thorium, which are among the heaviest known elements. It has been proved that as they very slowly disintegrate, they are transmuted into the stable elements, lead and helium. The resulting leads have the atomic weight of 206 and 208 respectively, as distinguished from the atomic weight, 207.18, of ordinary lead.

13 Bretz, J. H., " Geological Processes and the Earth's History," Ch. III in *The Nature of the World and of Man* (Newman, editor), University of Chicago Press, 1926, pp. 71–75, 82.

To calculate the age of a radioactive mineral we must know how fast lead is produced and how much lead is present. Chemical analysis readily answers the latter question. With reference to the other it has been found experimentally that a million grams of uranium produces 1/7400 g. of lead in a year, and that an equal amount of thorium produces 1/19,500 g. In other words, it requires 66 million years to change one per cent of uranium into lead. By determining, then, the ratio of lead present in a uranium mineral, one may deduce the age of the mineral.

Uranium, which is found in many igneous rocks, is practically always accompanied by varying quantities of lead. Since this lead has the atomic weight which distinguishes lead produced by the disintegration of uranium, it probably originated *in situ.* Mineral specimens of all geological ages from all regions of the earth have been analyzed and dated by this timepiece of lead ratios. The ages obtained are consistently small for rocks that are known, from paleontological or other evidence, to belong to late eras; the ages are consistently great for rocks of ancient epochs. The oldest rocks reported by Holmes[14] (lower pre-Cambrian, from Wodgina, West Australia) possess a lead ratio of .187, and are probably, therefore, more than 1200 million years old. Davis calculated the age of a specimen of pre-Cambrian uraninite from the Black Hills of South Dakota to be 1667 million years, a result greater than any previously published.[15] The original crust of the earth is probably much older than this, perhaps two or three times older. The reason for the latter estimate is that precise calculations have been made of the average amount of uranium lead in the granitic rocks of the outer layer of the earth's crust. According to an estimate reported by Russell,[14] about 4800 million years would be required to produce this amount of lead by the decay of uranium.

The preceding estimates, derived from a study of atomic disintegration, have no absolute value. Not all of the eight or more factors which conceivably may operate in the formation of lead under primeval conditions have been surely eliminated as unimportant. The results, however, are likely to remain relatively correct among themselves, and provide an important criterion against which to check estimates determined by other methods. Holmes has summarized the results obtained by eight different methods of estimating the age of the earth.[14] These results lie between one and five billion years, with an average of about two billion. He concludes that the minimum age of the earth is perhaps 1600 million years.

[14] Holmes, Arthur, *The Age of the Earth,* N. Y., Harper, 1927, pp. 73–80. *Cf.* Russell, H. N., *Scientific American,* April, 1928, pp. 321–322.

[15] Davis, C. W., "The Composition and Age of Uranium Minerals," etc., *American Journal of Science,* March, 1926, pp. 201–217.

9. Gradation and Geographic Cycles

We turn now to consider a major task of dynamic geology, the story of gradation. Gradation includes every process which transfers fragmentary materials from one part of the earth's surface to another. Wherever land appears above water, erosion by weathering begins. The appearance of rain aided greatly in wearing away the continents and filling the oceans. Running water carries incredible quantities of material into the ocean each year. At the present time the Mississippi River dumps a million tons of mud into the Gulf of Mexico every day.[16] Bretz declares that North America is being eroded by streams at the rate of more than an inch per millenium.[16] Holmes estimates that Great Britain, with an average height of 350 feet, is being worn away at the rate of one foot in three thousand years.[17] At this rate it could be reduced to sea level in about a million years. Indeed, at the rate indicated, Britain could have been moved into the ocean a thousand times since the dawn of life on the earth (provided, of course, that it had been restored an equal number of times).

Other agencies also operate to make the land lighter and the oceans heavier. The soluble materials which are carried into the seas are those of sodium, potassium, calcium, magnesium, and fluorine which are relatively heavier than the insoluble ones that remain behind, such as compounds of silicon and aluminum. Also, in the aggregate of geologic time, dust blown by the wind into the ocean is an important movement of material.

Thus, the surface of the earth is constantly being changed — elevated or depressed, covered or twisted — but this ever-shifting geography of land and sea proceeds so slowly that it is noticeable only to the ready eye of the geologist. Through long periods of time, however, vast continental areas may be radically altered. For example, during the Paleozoic era most of the eastern and central parts of the United States were depressed and covered with the waters of a great sea. In these waters there accumulated and hardened through long ages the sediments which later were elevated to form the present land surface of those areas.

If the denuding processes continued indefinitely, the highest continents evidently would become low, level plains, and finally the oceans would cover all the earth. A universal flood does not actually occur, however, not at all for want of time, but because the very wearing away and lightening of the continents is a promise that gravity will elevate and restore them as described in the next section. *A single period of uplift followed by the erosive cutting down to a plain is called a geographic cycle of erosion.* Some mountain ranges, such as the Appalachians, have passed

[16] Bretz, *op. cit.*, p. 59. [17] Holmes, *op. cit.*, p. 9.

through several cycles already. Since the close of the pre-Cambrian era there have been three great periods of elevation and erosion in Europe and about twenty minor ones.[18] Evidently these cycles require immense epochs of time. But, as a million miles is a short distance in astronomy, a million years is a short period in geology.

10. Isostasy and Uniformitarianism

In order to understand the processes involved in the making of ocean beds and continents, two important facts must be considered. The first is that the materials deep in the earth are twice as heavy as the superficial ones. The positive evidence for this fact is found in the measured differences in the transmission of earthquake waves. While the density of the earth as a whole is 5.5, that of a forty-mile crust is only 2.5. These deeper regions are denser because of pressure; they are denser also perhaps because heavier materials settled toward the center of the earth during its formation.

A second significant fact is the proof in recent years that the earth is relatively plastic. This property is required to explain the twisted and banded character of metamorphic rock, and the raising of continents. Rocks under great pressure flow like viscous substance. This fact has been experimentally demonstrated " by a brilliant piece of work with the aid of elaborate and expensive apparatus. Professor F. D. Adams, of McGill University, has first tightly encircled cylinders of Carrara marble in jackets of tough sheet iron. He has then submitted them to slow but irresistibly increasing pressure. As the strain passed their limit of crushing resistance, and while they were so tightly encased in the tough but yielding jacket that they could not crack, they have passed from cylinders an inch in height to discs of half this altitude and of correspondingly increased diameter. Yet they have never lost their cohesion, but have moulded themselves like so much wax. When removed from the jackets, the discs are as solid and homogeneous as were the original cylinders." [19]

If the terrestrial crust is light and plastic, what will occur if relatively heavy materials from underneath are extruded upon it? The lava-covered areas are likely to sink by degrees under the force of gravity, while the lighter regions will be elevated in compensation. Inequalities of weight in a plastic crust tend in the course of ages to be equalized laterally. In other words, flowing, folding, and faulting take place in the direction of a gravitational equilibrium of masses. This tendency to equilibrium has been

[18] *Op. cit.*, p. 47.

[19] Kemp, J. F., *Geology, A Lecture*, New York, Columbia University Press, 1912, pp. 9–10; quoted with permission of publishers.

formulated in the following *theory of isostasy* (Greek, *equal standing*): *the weights of matter under unit areas of the earth's surface tend to become uniform.* The materials of the earth tend to adjust themselves so that pillars of equal diameter in different regions have equal weights. Thus, a rhythmic submergence and elevation of continents periodically reverses or annuls the work of gradation. The earth's surface is not perfectly smooth because it is neither perfectly homogeneous nor perfectly fluid.

This bold conception which declares that mountains may float on a heavy substratum was suggested about seventy years ago by the Astronomer Royal, Sir George Airy. A surveying party in Northern India reported that the difference in latitude between Kalianpur and Kaliana as determined by triangulation was 5.″236 more than astronomical observation showed. It was inferred that at Kaliana, sixty miles from the great Massif of the Himalayas, the plumbline was attracted by the mountain and the result thereby falsified. Archdeacon Pratt calculated, however, that the error should be 15.″885, if the density of the mountains were 2.75 times that of water. Airy then suggested that this discrepancy must be due to the fact that the density of the mountains as compared with the substratum must be less than commonly supposed. When a lesser density was assumed, the errors disappeared. This surprising discovery led to the formulation of the theory of isostasy.[20]

This hypothesis has been tested and is being tested in various ways. It has been found that a swinging pendulum of proper construction "has a slightly shorter period of oscillation over the ocean basins than over the continental platforms. Furthermore, the lavas of oceanic volcanoes have a greater density than those of the continental platforms." [21] Very extensive studies of the United States Coast and Geodetic Survey "show clearly that the portion of the earth's crust covered by the United States proper is, on an average, in practically a state of complete isostasy." [22] In short, "the continents stand above the ocean floors for the same reason that icebergs rise above the surface of the ocean." Mountain ranges are higher because they are lighter; ocean beds are lower because they are heavier.

Isostasy at the present time retains the uncertain status of a working hypothesis. It assumes that the earth's crust extends to a uniform depth and varies in density. According to a rival theory, the crust need not vary much in density *if* it has different thicknesses in various regions. It is

[20] Joly, John, *The Surface History of the Earth,* Oxford, Clarendon Press, 1925, pp. 33–34.

[21] Bretz, *op. cit.,* p. 67.

[22] *Department of Commerce and Labor, Special Publication No. 12 in Geodesy,* Washington, Government Printing Office, 1912, p. 28.

not easy to decide between these two guesses. It may be that each holds a part of the truth.

Underlying all the investigations of the modern geologist is the basic assumption of uniformitarianism. This conception has supplanted the old dogma that high mountains, deep gorges, and other striking features of the landscape were produced in short periods of time by violent and dreadful catastrophes, such as the deluge in which Noah figured. *According to the accepted law of uniformitarianism, all geologic changes beginning with the Archeozoic era can be explained by the operation, often slow and continuing through long time-periods, of forces similar to those that are now acting.* The geologist believes that even small agencies will accomplish any given result if they are allowed sufficient time. And the geologist has at last won entire freedom to postulate as much time as he thinks necessary to explain the facts. As the sand and gravel carried along by the Colorado River during long ages have cut the Grand Canyon of the Colorado, these same forces of erosion, if given ample time, will raze the eight-thousand-foot plateau of Arizona to a vast low-level plain, perhaps to a shallow sea such as once existed before in this region.

The geologist has endowed the maxim of Herodotus with new and richer meaning: "If one is sufficiently lavish with time, everything possible happens." If we could telescope geologic history into an hour and survey its changes in an immense moving picture, we should see mountain ranges rise and fall like gigantic billows. We should see volcanoes spread out their heavy streams of lava, only to be swallowed up in a moment by the onrushing waters of new seas. Oceans and glaciers and tropical climates would advance and recede, painting the landscape with kaleidoscopic colors or utterly devastating it. Strange races of plants and animals would appear, live their short lives, and vanish forever. In the last three or four seconds man would appear upon the earth, to work speedily his marvelous transformations upon the ancient crust of the earth.

C. PHYSICS

11. The Field of Physics

Physics is the most fundamental of the natural sciences because it treats of the general properties of matter and energy. It occupies a middle position between abstract mathematics and concrete biology. It is to be distinguished also from the chemical study of the kinds and compounds of matter. Astronomy and geology, as we have seen, make intensive investigations of other aspects of the material universe. Of all the natural sciences, physics is at once the most mature and the most rapidly developing at the

present time. Its advance in the first decades of the twentieth century has been, declares Professor Haas of Vienna, "more revolutionary than any in the whole history of science."

The field of physics used to be divided into half a dozen studies concerned with moving bodies, heat, sound, light, and electricity. These studies were sometimes called respectively mechanics, acoustics, thermodynamics, optics, and electromagnetics. These distinctions, however, ceased to be fundamental when the new physics coördinated all physical phenomena under the concept of atomic activity. The old divisions are still practically useful, and indicate some of the special problems of physical science. The investigation of radioactivity and other invisible radiations has become an important new branch of physics.

The science of physics began about 1600 when Galileo undertook to describe moving bodies under experimental conditions. He had the boldness to suggest that physical phenomena be studied by direct observation rather than by reading the works of Aristotle. He trusted his own perceptions more than the words of authority. He exemplified the ideal of investigating material systems under the simplest artificial conditions that can be devised. For example, since falling bodies fall inconveniently fast for exact observation, he invented the inclined plane and let balls roll down as slowly as he chose. Then he tried out one hypothesis after another in his search for the law of their acceleration. He first guessed that acceleration and distance stand in the simplest direct proportion. Careful experiments with his reliable water clock disproved this hypothesis. Next, he proposed that the velocity increased uniformly with the time. He finally proved that it is proportional to the square of the time. Since he regarded nature as "a book written in mathematical language," he believed that the demonstrations of science could and should be developed in mathematical form. With these methods and with this spirit of Galileo all modern scientists feel a deep kinship.

12. The Atomic Theory

All matter exists in a solid, liquid, or gaseous state, and has the universal properties of inertia, gravitational attraction, mass, volume, density, and atomic structure. We shall restrict our attention to the last basic characteristic.

Physicists now regard all matter as an assemblage of exceedingly minute corpuscles called atoms, or of combinations of these atoms called molecules. *Atom* is a Greek word which means *that which cannot be cut.* The atomic theory originated with two Greek philosophers, the little-known Leucippus and his great disciple, Democritus (460–370 B.C.). They taught

that the whole universe is constituted of an infinite number of very small entities which are indivisible, indestructible, and unchangeable. Their opinion was based upon such everyday observations as the drying of clothes, the mixing of wine and water, and the crumbling of rocks into sand and dust. They bequeathed to the world a brilliant and fertile idea, but they failed to establish it upon an experimental foundation. Until the days of Dalton, scientists continued to regard matter as continuous.

John Dalton (English, 1766–1844) revived the atomic theory, and by his researches between 1802 and 1808 he gave it an experimental and quantitative basis. Various observations suggested the theory to him, notably the fact that liquids absorb different amounts of gas according to their nature and pressure. He found also that for the same quantity of carbon precisely twice as much oxygen by weight was present in carbon dioxide as in carbon monoxide.

The atom is now known to be an exceedingly minute particle or organism. Various ingenious methods have been devised to determine its size. Films of oil, for example, have been teased out on clean water to a thickness of less than a ten-millionth of an inch. A convergence of evidence indicates that the atom is of the order of a hundred-millionth of an inch in diameter. It is as much smaller than a golf ball as the latter is smaller than the earth. A hundred thousand atoms placed side by side would make a line equal to the thickness of a cigaret paper. Adams points out that "It is a rather interesting coincidence that physically man is nearly a mean proportional between an atom and a star. It requires about 10^{27} atoms to make a human body, and the material of 10^{28} human bodies to make a star." [23]

An atom is no longer regarded as an indivisible and ultimate ball. On the contrary, an atom consists mostly of empty space marked by peculiar properties because it is under the influence of a few mites of electricity.[24] *Atoms of every sort contain two components only: negative charges of electricity called electrons* (Greek, *amber*) *and positively charged particles called protons* (Greek, *first*) *or positive electrons.* The same quantity or charge of electricity normally exists on both. At the present time physicists are unable to reduce material things to simpler components than these twin wonders, the electron and the proton.

Electrons "flow"; protons, as a rule, do not flow. An exceedingly swift stream of positive electrons is called an electric current. An electric battery or dynamo is an electrical pump for forcing a stream of electrons through a conductor of iron or other material.

[23] Adams, W. S., "The Interior of a Star," *Scientific Monthly*, April, 1928, pp. 363–371.

[24] *Cf.* Andrade, E. N. da C., *What is the Atom?* New York, Harper, 1927, p. 52.

Since unlike electric charges attract each other, electrons and protons form tiny systems which are more or less complex and stable. *Such an electrically neutral system containing an equal number of electrons and protons is an atom; a union of two or more atoms is called a molecule.* An atom of hydrogen, the lightest atom known, contains only one electron and one proton. The proton, therefore, seems to be identical with the nucleus of the hydrogen atom. In all other atoms the nucleus consists of a bundle of protons and bound electrons surrounded by an intense electrical field. These nuclear electrons perhaps serve, as Knowlton suggests, "as a kind of cement, or binder, to hold the naturally repellent protons together."[25]

Around the nucleus at relatively great distances revolve two (helium), three (lithium), or more, planetary electrons in more or less complicated orbits. *Differences in substances are supposed to be due solely to differences in the number and arrangement of electrons and protons in their atoms and molecules.* When an atom or molecule is split up, its parts become charged particles called ions (Greek, *travelers*). The mass of an electron is now known to be 1/1845 of the mass of a hydrogen atom. The weight of the hydrogen atom is 1.64×10^{-24} g.; the weight of the electron is 9×10^{-28} g.[26] But while the proton is nearly 2000 times heavier than the electron, the electron is probably much larger than the proton.

13. Some Experiments with Atoms

R. A. Millikan (American, b. 1868) received the Nobel prize in physics for 1923 for measuring exactly the charge of an electron and for other extraordinary researches in atomic physics. He made this measurement in some classical oil-drop experiments culminating in 1910.[27] His apparatus was as ingenious as it was simple. With an atomizer he sprayed oil droplets about 1/25,000 of an inch in diameter over two charged plates. Occasionally a particle drifted through a pinhole in the upper plate into the thin layer of dust-free air between the plates. There it settled under gravitation at the rate of 1/30 of an inch per second. The particles acquired charges by friction as they left the atomizer, or were ionized by exposure to X-rays or radium radiations. When the droplets were strongly illuminated and observed through a microscope, they looked like bright stars

[25] Knowlton, A. A., *Physics for College Students: An Introduction to the Study of the Physical Sciences,* New York, McGraw-Hill, 1928, p. 228; (an excellent textbook).

[26] *Op. cit.,* pp. 79, 213, 217.

[27] Millikan, R. A., "The Electron and the Light-Quanta — What are They?" *Scribner's Magazine,* Vol. 77 (1925), pp. 75–84

against a black background. From data thus secured the charge was calculated.

The charge on an electron was determined by exact measurements of its movements. By throwing on and off an electric field between the plates a particle under observation was kept travelling up and down between them, sometimes for hours. Occasionally an extraordinary phenomenon occurred: the velocity of the droplet would abruptly increase. This could only mean that the particle had " captured an ion " and thus added to its own charge. Millikan declares, " The measurement of electrons . . . involves observations of the foregoing sort upon thousands of drops of various sizes, made from a number of different substances, surrounded by a large number of different gases at widely different pressures." [27] He asserts that he never found an ion which " did not have either exactly the value of the smallest charge ever captured or else a very small multiple of that value." [28] He determined this smallest invariable charge as 4.774×10^{-10} electrostatic units. This charge is condensed into a sphere with a radius of about 1/50,000 of the radius of the atom.[29]

The preceding picture of the atom has followed the fruitful solar-system model suggested by Rutherford and recently developed by the Danish physicist, Niels Bohr. He imagines that the electrons move very swiftly around the nucleus in definite and relatively fixed orbits. The heavy nucleus moves in a comparatively small circle because it is near the atomic center of gravity. The speed of the electron is enormous: it completes its orbit or year more than a billion times in every millionth of a second. Other models of atomic structure have been proposed, but none of them is free from difficulties; it may be that the atom is quite unpicturable. It seems quite certain, however, that electrons are the bricks of which the cosmos is made.

That most of an atom is empty space has been demonstrated in the cloud-chamber experiment devised by C. T. R. Wilson, of Cambridge University.[30] His experiment is one of the most beautiful and wonderful in the world of science. It is well known that radium constantly shoots off tiny particles, called alpha-rays, with a double positive charge. The spectroscope shows that these consist of nuclei or ions of the light gas, helium; they are helium atoms which have lost their only two planetary electrons. This phenomenon realizes one of the dreams of the alchemist: the trans-

[28] Millikan, R. A., *The Electron* (ed. 2), University of Chicago Press, 1924, pp. 71–72.

[29] *Cf.* Millikan, " The Structure of Matter," Ch. III in *Contributions of Science to Religion* (S. Mathews, editor), New York, Appleton, 1927.

[30] *Cf.* Bragg, Sir Wm., *Concerning the Nature of Things,* New York, Harper, 1925, pp. 20 ff.

mutation of one element into another. The alpha particles start with a speed of more than ten thousand miles per second but end their courses in two or three inches. That they should go so far is the marvel that is to be explained.

Wilson's apparatus consisted of a brass cylinder with a glass top in which a piston may be moved. A speck of radium is mounted on a little shelf and the atmosphere in the cylinder is kept moist. When the piston is suddenly dropped, the expansion causes a chilling of the atmosphere. The invisible moisture tends to condense into tiny droplets to form fog, but prefers to collect on dust or charged particles rather than originate independent droplets. An abundance of charged particles is provided by the alpha-rays smashing through the atoms of the air.

If, now, the chamber is brightly illuminated and the piston suddenly dropped, the fog appears in white lines against a black background. In a fraction of a second the lines disperse. They are the visible trails of helium ions. Among thousands of flashlight photographs a few have been found in which a line suffers a deflection near the end of its course. At a meeting of the American Chemical Society in 1928, Harkins of the University of Chicago reported that he had observed only thirty forked rays in a million helium fog lines which had been photographed in a hundred thousand moving pictures.

In interpreting this experiment we may ask why the helium ion travels so far, since there are about a hundred thousand intervening atoms of oxygen and nitrogen. We should expect it to be turned quickly aside like a billiard ball which has been shot into a collection of balls. The best answer to the question is that *the ion goes straight through the atoms in its path.* Ordinarily each atom has its own domain as defined by its outermost shell of electrons. When atoms meet, these electrons, being of like charges, repel each other, and thus the atoms are kept apart. But when one atom approaches another at very high speed, as in the case of the alpha particles, we must suppose that it shoots right through the atoms which lie in its way. We conclude that *the components of an atom must occupy an exceedingly small fraction of the space of the atomic system as a whole.* The occasional deflections must be due to particles colliding with the nuclei of air molecules. Since the deflections are sometimes great, the nuclei of oxygen are undoubtedly very heavy in comparison with an alpha particle. More than a century of the most diversified testing has made the atomic theory one of the basic certainties of contemporary science, and the most important conception both in physics and chemistry.

14. Applied Physical Science

The swift development of theoretical physics in the twentieth century is matched by a remarkable expansion of applied science. Applications of physical science have introduced a multitude of new wonders into the factories, streets, and homes of civilized nations. The purpose of applied science is to direct the great sources of energy in nature for the use and benefit of man.

The most important applications of physical science are executed by men called engineers. They are concerned either with the making and using of inventions and machines, or with the designing and constructing of "public works" of diverse kinds. *A branch of engineering may be defined as any organized application of science and scientific method which requires technical training and a special knowledge of materials and machinery.* New branches of engineering are gradually developing as new bodies of knowledge are systematically and technically applied. The chief branches of contemporary engineering are the following:

1. *Aeronautical engineering.*
2. *Agricultural engineering.*
3. *Architectural and structural engineering:* buildings, ships, etc.
4. *Chemical engineering.*
5. *Civil engineering:* surveying; the making of roads, railroads, bridges, canals, irrigation systems, and other public works. Military, sanitary, and hydraulic engineering, navigation, and agricultural engineering overlap civil engineering to large extents.
6. *Electrical engineering:* production, transmission, and utilization of electrical energy; communication by wire and wireless; television; etc.
7. *Mechanical engineering:* testing of materials; machine and tool making; steam, gas, and other engineering; motor vehicles and other modes of transportation; heat and marine engineering.
8. *Mining engineering and metallurgy.*

When President Stratton of the Massachusetts Institute of Technology was asked to name the seven great wonders of the modern world, he replied that it would be easier to mention seven hundred and seventy-seven. He then endeavored to state the nine most important contributions of modern science.[31] His list follows: (1) The discovery of bacteria and the application of bacteriology to human welfare; (2) the progress of our knowledge of the constitution of matter and radiation phenomena; (3) the progress of electricity as to light, power, and communication; (4) the internal combustion engine and its application; (5) modern methods of structural building with both metal and cement; (6) modern metallurgy;

[31] *Popular Science Monthly,* February, 1927.

(7) processes of food preservation, including canning and refrigeration; (8) aircraft and aerial navigation; (9) the development of machinery to lessen the burden of labor and to increase its output.

The Titans of mythology are pygmies beside the colossal machines which modern man has made to be his untiring servants. It is not easy to decide which of the many existing mechanical wonders is the most complicated of all. A type-setting machine, such as the Mergenthaler linotype, a metropolitan machine-switching telephone system, and a modern calculating machine — each has its own kind of extraordinary complexity.

One of the most notable of calculators is the integraph developed at the Massachusetts Institute of Technology by Dr. Vannevar Bush and several assistants.[32] This electrical thinker is designed to perform the difficult and laborious task of solving any total differential equation of the second order. The operator first transforms the given problem into an integral equation, then sets and starts the machine, which carries out the processes of integration and draws the curve of the desired solution. Thus in a few minutes or hours accurate results may be obtained mechanically which would require days or weeks of mental labor.[32]

We have yet to mention three remarkable machines which may be the most complicated ever devised by man. Of these perhaps the third in order is the automatic bottle-making machine, designed in part by an English lawyer, Francis Redfern, and first constructed in 1920. It is made up of any number of units from 6 to 15. The 15-unit machine contains 17,089 parts exclusive of 10,777 bolts and nuts. It may be operated by one man. As many different kinds of bottles can be manufactured at the same time as there are units. A unit may be removed and replaced by a different one in 25 minutes. A 10-unit machine working 24 hours a day will produce 537,552 pint bottles (12 to the English gallon) a week. A 15-unit machine fitted to make smaller bottles could produce more than a million a week.

Second in order may be the Hoe 24-cylinder multi-color printing press, which is said to be the largest in the world. It can produce half a million finished newspaper pages in an hour. It is composed of more than sixty thousand separate pieces, and weighs approximately half a million pounds. It prints, folds, and delivers many different products with various numbers of pages and combinations of color. When printing in four colors, on three rolls of paper, this press can deliver 384,000 pages an hour. Its capacity can be increased as the number of colors is reduced.

In the opinion of the editors of *Machinery,* the most elaborate machine

32 See Bush, V., and Hazen, H. L., "Integraph Solution of Differential Equations," *Journal of the Franklin Institute,* November, 1927; Bush, V., "The Mechanical Solution of Engineering Problems," *The Tech Engineering News,* March, 1928.

ever built is the automatic automobile-frame factory of the A. O. Smith Corporation of Milwaukee, Wisconsin. It is a remarkable combination of mechanical, electrical, chemical, and hydraulic engineering. Practically the whole plant is a single automatic machine in which unit machines and conveyors are controlled in synchronism. The raw steel material for the frames passes into the "machine" at one end of the factory and automatically moves along step by step as 552 operations are automatically performed upon it. At the end of two hours the steel goes back to the shipping yard in the form of completely shaped, machined, riveted, painted, and finished frames. These frames have even been accurately inspected by mechanical means. On an average, 600 tons of steel enter the plant daily, and the maximum production per day is 10,000 frames, or about one every six seconds. A complete change of tools for making frames of different specifications is accomplished in six to eight hours. About 200 men are employed to supervise the equipment. This is one fifth the number needed for equal production in a semi-automatic plant. As man devises more machines to meet his physical needs, he wins more time for developing and satisfying other needs.

15. Summary View of the New Physical Universe

We have seen how all matter is atomic: it is composed of electrons and protons, that is to say, of electrical charges. In modern physics, electricity has taken the fundamental place once occupied by matter. But electricity, too, is essentially atomic. According to the revolutionary quantum theory (established in 1900 by Max Planck, German, born 1858), energy also is atomic; it is shot out from the atom in tiny units or irreducible quanta, like bullets from a machine gun rather than like water from a hose. Electricity and energy are the fundamental concepts of contemporary physics. Matter is probably a compound of these. The status of a fourth concept, ether, is very problematic at the present time. The source of every kind of energy is to be sought within the atom.

In the opinion of d'Abro "the greatest advance in our understanding of nature that philosophy has yet witnessed"[33] is the theory of relativity. This bold and revolutionary view of nature has been created by the genius of Albert Einstein (German, born 1879). It is the product at once of ultra-refined experimentation and of tremendous mathematical reasoning. We have space only for stating its essence without history or evidence.[34]

[33] d'Abro, A., *The Evolution of Scientific Thought from Newton to Einstein,* New York, Boni & Liveright, 1927, pp. v and 480.

[34] See Heyl, P. R., "The Common Sense of the Theory of Relativity," *Scientific Monthly,* December, 1923, pp. 513–526; and "The Present Status of the Theory of Relativity," *Scientific Monthly,* Vol. XXIII (1926), pp. 65–70.

The first principle of Einstein is that the speed of light is the same for an observer anywhere in space in whatever direction he is moving and however fast, provided this speed is measured by the observer at rest relative to his frame of reference. From this postulate a stubborn contradiction apparently follows: a wave train of light may pass, with the same velocity, two bodies moving with different velocities. Velocity of course is a ratio between distance and time, length and duration. Einstein proceeded to describe a new world with a kind of space and time in which the above inconsistency would disappear.

The second of Einstein's two basic postulates is that length and duration are not absolute but relative, that is, having values dependent upon the motion of the observer. In other words, if two systems are in relative motion, the time and space intervals of one will not be the same when applied to the other.

Length is not an intrinsic and fixed property of an object. The same yardstick has different lengths for observers passing it at different velocities. If two observers are in relative motion and one measures the other's world, he must *decrease* his measurements by the following ratio: $\sqrt{1-v^2/c^2} : 1$, where v is the velocity of the object and c is the speed of light. Similarly, there is no absolute or universal second of time. Time measurements of a world in relative motion must be *increased* by the basic ratio just indicated. From the relativity of duration it follows that there is no universal "now." What is "now" in one frame of reference may be past in another and future in a third.

In short, measuring rods in relative motion must be shortened, durations lengthened, and simultaneity disrupted where events are spatially separated. Einstein goes on to show that pressure, temperature, and gravitation also must be relative. The theory is revolutionary because the physicist's measuring instruments themselves become variable under certain circumstances. Only the speed of light and electronic charge remain absolute.

A consequence of the theory of relativity is that space and time become shadows or abstractions of a fourfold realm of "events" or "incorporated motions." The physical world is a space-time world in which nothing exists in space which does not also happen in time. This world can be described only by a non-Euclidean geometry employing four coördinates or dimensions, time and the three old dimensions of space. The prevalent tradition that matter exists by itself in a three-dimensional realm has proved to be an unreal abstraction. We have suggested some ways in which the theory of relativity has freed us from the bondage of many dogmas and tremendously enlarged our outlook upon the world.

The astronomer has accustomed us to gigantic distances and empty

spaces. The geologist has made us familiar with immense periods of time filled with the slow transformations of mighty forces. The physicist opens to our vision an infinitesimal world, where incredibly small forces act with incredible speed. We may add that the chemist and biologist have revealed to us concrete forms of matter in fascinating and infinite variety. Now the relativist tells us that the hoary conception of a three-dimensional world is a fictitious abstraction, and that there is no universal second, meter, or " now." He declares that if we would know nature as it is, we must, by sheer mathematical endeavor, think our way into an unpicturable universe which somehow curves in upon itself, boundless and yet finite.

D. CHEMISTRY

16. The Definition and Problems of Chemistry

No definite boundary line exists between physics and chemistry. Both treat the same field of physical nature from different points of view. *While the physicist is primarily concerned with the general properties of atoms and energy, the chemist investigates the kinds of substances and their possible combinations.*

A rudimentary distinction is commonly made between physical or mechanical mixtures and chemical compounds. Examples of the former are flour and soda, sugar and water, a handful of soil, or a piece of granite. The components of such mixtures can sometimes be separated by physical means. Water, for example, may be evaporated from a sugar solution. If a magnet is drawn over a mixture of sulphur and iron filings, the metal particles are drawn off. If, on the other hand, the original mixture is heated, a choking yellow gas is given off and a new black substance is left behind which the magnet does not attract. The deep alteration that has taken place is called a chemical transformation. Other chemical transformations occur when iron rusts, magnesium is burnt, or marble is eaten away with hydrochloric acid. In the above cases heat and magnetism are examples of phenomena which are investigated in physics.

Chemistry is a natural science which treats of the composition, properties, and transformations of particular substances. The chemist does not describe knives, pans, vases, or chairs, as such, but iron, tin, porcelain, wood, gunpowder, and a multitude of other kinds of matter.

The chemist confronts three general problems in carrying out his task. First of all, he seeks to find and describe accurately the smallest number of elements of which he may regard all other substances as compounds. *An element is a substance which cannot be separated into simpler kinds by any known chemical process.*

The second task of the chemist consists in discovering the laws of affinity and change among the elements. Finally, the chemist may become " an architect and designer of chemical structures," and build up new substances having prescribed properties. The achievements of synthetic chemistry are among the most brilliant of modern science. These accomplishments are presented in an interesting way in Slosson's *Creative Chemistry.* J. Johnston declares, " The so-called coal-tar or aniline dyes bear about the same relation to coal-tar or aniline as a steel battleship does to a heap of iron ore." [35]

17. The Chemical Description of Substances

About two hundred and fifty thousand substances have been chemically analyzed, and others are frequently being found in nature or prepared in the laboratory. Most of these existing substances can be analyzed into simpler ones, but a few cannot. The latter substances are the elements. At the present time ninety elements are known. Of these hydrogen is the lightest, oxygen the most abundant, and radioactive uranium the heaviest. About half of the elements exist in small quantities. Two of them are liquids (mercury and bromine); about ten are gases; and about seventy (including eighteen rare earths) are regarded as metals; some are difficult to classify at all.

All material substances which are not themselves elements are combinations of elements. Sugar, for example, is composed of carbon (charcoal) and the two invisible gases, oxygen and hydrogen. Let us consider what happens when sodium and chlorine are brought together. Sodium is a soft putty-like metal which floats in water. It reacts so violently with water that if it were put into the mouth, disastrous consequences would follow. Chlorine, on the other hand, is a green gas with a most pernicious odor. It was used as a poison gas in the World War. When these elements are united, the striking properties just mentioned disappear, and a fine powder is formed. It is called sodium chloride and is nothing other than common table salt. We shall see how some compounds are very complex.

Elements are organized in multitudinous ways. These combinations are made or changed in five typical ways. One transformation consists in *combination;* for example, when iron rusts, iron and oxygen unite to form a new substance called ferric oxide. *Decomposition* is a second kind of change; it takes place when an electric current breaks down the mineral bauxite into aluminum and oxygen. A third mutation is *displacement:* when sodium is dropped into water, it takes the place of some hydrogen,

[35] " Chemistry," Ch. III in *The Development of the Sciences* (Woodruff, editor), New Haven, Yale University Press, 1923.

which comes off as a gas. Sometimes, too, an *exchange* of corresponding parts takes place between two compounds. Finally, the elements of some compounds can undergo *rearrangement* without any loss or addition of elements.

Although the properties of a compound are usually very different from those of its constituents, the latter are by no means destroyed in the synthesis. Rather, they enter into intimate federations called molecules. *A molecule consists of a definite number of elementary atoms united in fixed proportions.* Thus, in salt, sodium and chlorine are always represented in the proportions by weight of 22.98 to 35.46; the ether used for anaesthetic purposes is made up of carbon, hydrogen, and oxygen in definite proportions.

All samples, then, of a pure substance, whatever their origin, always contain the same elements in the same proportions by weight. A molecule is the limit to which the fractioning of a substance can be carried without destroying that ensemble of properties by which it is identified. This definition of a pure substance is the first great law of chemical combination; it is often called *the law of constant proportions.*

Molecules differ immensely in size and complexity. Many elements themselves normally exist as molecules containing two or more atoms. Thus free oxygen exists as a molecule of two atoms. The uncommon pungent gas called ozone contains three atoms of oxygen. Carbon atoms enter into different arrangements to form molecules of substances having different properties; for example, charcoal, graphite, and diamonds are all made up of carbon atoms. The paraffin, dimyricyl, is an example of a very complex molecule; it contains 60 carbon atoms and 122 hydrogen atoms. Molecules in living cells may contain thousands of atoms. Few compounds are composed of more than four elements; the vast majority contain three; of these three, oxygen is usually one. Molecules are far too small to be seen directly under the most powerful microscope.

Atoms, then, are the alphabet of which countless molecules may be formed. Individual molecules are the entities which determine the properties of gross matter. A chemist is a specialist in the analysis, description, and building of molecules. When molecules are decomposed or broken down by dissolution in water or by electrolysis, charged particles result. *These incomplete molecules are called ions.* An atom which has lost one or more electrons is also called an ion. In Figure 6 the particles with which the chemist has to do are arranged in the order of increasing complexity.[36]

In studying a given substance the chemist wants first to know what elements compose it. For summarizing his results he employs a compact

[36] Adapted from Masson, Irvine, *Chemistry in the Twentieth Century* (E. F. Armstrong, editor), New York, Macmillan, 1924, p. 25.

and beautiful system of symbols. Simple signs are used to indicate what elements are present in a molecule and in what proportions. A classification of compounds by reference to their external marks would be exceedingly cumbersome in view of their number. But elements are few, and to each, one or two letters are assigned for one reason or another. Eleven have been given symbols from their Latin names, as Fe for iron (Latin, *ferrum*), and Au for gold (*aurum*). P stands for phosphorus, the light-bearer; H for hydrogen, the water-producer; and A for argon, the lazy one. The symbol, He, signifies helium, which means *sun;* Il represents illinium, which is named for the state of Illinois; it is the only element discovered by an American which fills a blank space in the periodic table.

7 matter in bulk
6 colloid particles crystal units
5 molecules
4 molecular ions + −
3 atoms
2 atomic nuclei or ions +
1 protons + electrons −

Fig. 6. Particles of Matter in Ascending Complexity

An inferior number or subscript indicates the number of atoms, and therefore the proportional weights, of the combining elements. Thus H_2O means that two atoms of hydrogen and one of oxygen are united to form a molecule of water. Similarly, ordinary sugar contains the ratio of atoms indicated in the formula: $C_{12}H_{22}O_{11}$; $C_{17}H_{35}COONa$ stands for stearin soap, and $CH_2ICOOC_2H_5$ (ethyl iodacetate) for the terrific tear-gas used during the World War. This system also aids in discovering new substances. If we know, for instance, that the principal compounds of chlorine, oxygen, and hydrogen are $HClO$, $HClO_3$, and $HClO_4$, we cannot help noticing the gap in this series and wondering how it may be filled. $HClO_2$ has been found in fact to exist, but it is difficult to obtain and preserve.

The chemist not only analyzes a substance into its elements, but determines exactly a great variety of other properties which it may possess. In describing a chemical substance he looks for a special combination of the general properties of matter which it is the business of the physicist to determine. Thus, copper is distinguished by its color, rubber by its elasticity, and ether by its odor. We may inquire also concerning the density, taste, hardness, solubility, boiling and melting points, conductivity for heat and electricity, optical spectra, crystalline habits, and other general properties.

18. Atomic Weights and Some Chemical Laws

There is one characteristic of substances which is of supreme importance in chemical studies; namely, the mass or comparative weight of

elements, because the mass of an element always leaves an indelible trace, however it may seem to disappear or change in a chemical reaction. Robert Boyle (Irish, 1627–1691) first insisted that, contrary to the superficial evidences of the senses, elements are not destroyed in chemical transformations. The modern era of chemistry, however, really began at the end of the eighteenth century when Antoine Laurent Lavoisier (French, born 1743, guillotined 1794) introduced the unremitting use of the balance in tracing the identities of weight amid the changing aspects of substances. For this reason he has been called "the founder of quantitative chemistry." He also set forth a clear conception of chemical composition. His great systematic work, *Traité élémentaire de chimie* (1789), transformed the study of chemistry.

Lavoisier laid down the axiom that the quantity of matter is the same at the end as at the beginning of every chemical change. For example, in the burning of a candle, the weight of the candle and of the oxygen consumed is exactly equal to the weights of the products of combustion. The form of matter has radically altered, but the amount of matter remains identical. This principle is called the *law of the conservation of mass: the sum of the masses of all substances taking part in any chemical or physical change is constant.* It is the second fundamental principle of chemical investigation.

The chemist also assumes the *law of the conservation of energy;* the total energy in a closed or limited system neither increases nor diminishes. When energy seems to disappear, the scientist looks for it in some other form into which it has been converted.

The physical law of the conservation of mass becomes more definite in the chemical law of constant proportions already stated above. Not only does the chemist assume that each element enters into chemical combination with the same characteristic weights, but he goes one step further in the *law of multiple proportions,* another basic principle of chemistry: *If one element can form more than one compound with a second element, the different quantities of the first stand to each other in the ratio of simple whole numbers.* For example, in CO_2 (carbon dioxide) there is just twice as much oxygen by weight as in CO (carbon monoxide).

Each element has its distinctive weight, called its relative or atomic weight. *The atomic weight of an element is the weight of one of its atoms as measured by a unit equal to one-sixteenth of the weight of an oxygen atom.* Oxygen has been chosen as a standard or basis of comparison for two important reasons: other atomic weights are brought near to whole numbers; and oxygen combines with all other elements except fluorine and the inert gases. The atomic weights of the twenty lightest elements are indicated in Table II.

Table II. Partial List of Chemical Elements

Atomic No.	Name of Element	Symbol	Atomic Weight	No. of Valence Electrons	Experimental Valence [37]	Mass Nos. of Isotopes in Order of Decreasing Abundance
1	Hydrogen	H	1.008	1	1, −1	
2	Helium	He	4.00	0	0	
3	Lithium	Li	6.940	1	1	7, 6
4	Beryllium / Glucinum	Be / Gl	9.02	2	2	
5	Boron	B	10.82	3	3	11, 10
6	Carbon	C	12.000	4	4, −4, 2	
7	Nitrogen	N	14.008	5	−3, 3, 5	
8	Oxygen	O	16.000	6	−2	
9	Fluorine	F	19.00	7	−1	
10	Neon	Ne	20.2	0	0	20, 22
11	Sodium	Na	22.997	1	1	
12	Magnesium	Mg	24.32	2	2	24, 25, 26
13	Aluminum	Al	26.97	3	3	
14	Silicon	Si	28.06	4	4, −4	28, 29, 30
15	Phosphorus	P	31.027	5	−3, 3, 5	
16	Sulphur	S	32.064	6	−2, 6, 4	32, 34, 33
17	Chlorine	Cl	35.457	7	−1, 1, 3, 5, 7	35, 37
18	Argon	A	39.91	0	0	40, 36
19	Potassium	K	39.096	1	1	39, 41
20	Calcium	Ca	40.07	2	2	40, 44

Chemists long ago noticed that elements may be distributed into certain natural groups, such as the alkali metals, because of similarity of properties. In 1865 the Englishman Newlands showed that if the elements then known (about sixty) were arranged in the order of their increasing atomic weights, similar elements appeared at regular intervals along the series. He observed that every eighth element, as a rule, was "a kind of repetition of the first," and he called this striking recurrence "the law of octaves."

In 1869, D. I. Mendeléeff (Russian, 1834–1907) and Lothar Meyer (German, 1830–1895) independently constructed a more elaborate system of the elements which is called Mendeléeff's periodic table of the

[37] Noyes and Beckman, "The Structure of Atoms as a Periodic Property and its Relation to Valence and Ion-formation," *Chemical Review,* June, 1928, pp. 101 ff.

elements. Mendeléeff stated the *periodic law* thus: "The properties of elements are periodic functions of their atomic weights." Some examples of periodic properties are: density, melting point, combustibility, and coefficient of expansion.

Mendeléeff's rhythmic arrangement of the elements in eight groups succeeded remarkably in bringing together in a compact, orderly, and suggestive scheme a vast number of facts concerning chemical properties. It revealed several erroneous atomic weights and helped tremendously in finding many correct ones. This systematic correlation, however, compelled Mendeléeff to recognize certain gaps in his table. He predicted that some day these empty places would be filled by newly discovered elements. From the position of the gaps he deduced the atomic weights and other definite characteristics of three unknown elements. In less than twenty years all three had been discovered: gallium, scandium, and germanium. They were named by their discoverers in honor of their respective countries, France (Gallia), Scandinavia, and Germany. They were found to have almost exactly the properties which Mendeléeff had specified in advance.

This remarkable rhythm suggested that some basic principle of unity must exist which would explain the harmony of the system and open new fields of investigation. After a long search, this principle has recently been found. It is called atomic number.

19. Atomic Numbers and Chemical Activity

In the discussion of physics we noted that atoms contain equal numbers of electrons and protons, and that the protons create the mass of the atom. Thus, hydrogen consists of one electron circling around one proton or positive hydrogen nucleus. Now, if the nucleus of an atom other than hydrogen consisted solely of protons, we should expect its mass to equal its positive charge. As a matter of fact, the mass of the heavier atoms is always two or more times greater than the positive charge. Sodium, for example, has an atomic weight of 23, compared with hydrogen, but has only 11 planetary electrons. The remaining twelve must be compactly bundled up with the protons to form the nucleus of the atom. The structure of other atoms is explained in a similar way.

The number of electrons outside of the nucleus is called the atomic number of the atom or element. It is identical with the net positive charge of the nucleus, which is equal to the excess of protons over electrons in the nucleus of the atom. The atomic numbers of the elements form a series of ordinal numbers from 1 to 92. The series is complete except that no elements are yet known which have atomic numbers 85 and 87. In this series hydrogen is number 1 and uranium number 92. There are four

instances in which the order of atomic weight is opposite to the order of atomic numbers; for example, argon and potassium. Atomic number is now regarded as a more fundamental property of elements than atomic weight. "All the properties of an atom, save mass and radioactivity, depend upon the atomic number."[35] *A chemical element may now be exactly defined as a substance all the atoms of which have the same atomic number.*

Chemists were long perplexed by the fact that atomic weights are not simple multitudes of hydrogen. All but a few of them in fact are fractional. Thus, the atomic weight of chlorine gas is neither 35 nor 36, as we might expect, but 35.46. Aston has proved, by some ingenious physical experimentation and precise measurement, that some atoms of chlorine have a mass of 37 and others a mass of 35. They are mixed in such a proportion that their *average* weight is 35.46. *Substances of this sort which have identical atomic numbers and chemical properties but different weights are called isotopes.* They cannot be separated from one another by chemical methods. The atomic numbers and the known isotopes of the first twenty elements are indicated above in Table II. If an element has no isotopes, its atomic weight should be a whole number. This important discovery of isotopes has greatly simplified our understanding of chemical substances.

Since chemical properties depend upon the electrons outside the nucleus, we must consider further the arrangement of these planetary electrons. They are supposed to exist or move in a small number of definite spheres or orbits. It is important now to know how many electrons are required to complete each of these spheres.

It is probable that the six rare or inert gases, as indicated in Table III, represent the succession of atoms which have completed shells.[38] The reason for this supposition is that these elements are exceedingly stable and form no chemical compounds whatsoever.

Table III. The Inert Gases

Name of Gas	Atomic No.	Number of Negative Electrons in Successive Completed Shells
helium	2	2
neon	10	2 8
argon	18	2 8 8
krypton	36	2 8 18 8
xenon	54	2 8 18 18 8
radon (or niton)	86	2 8 18 32 18 8

[38] *Cf.* Haas, A. E., Ch. V, "The Theory of the Chemical Elements," in *The New Physics* (trans. by Lawton), New York, Dutton, 1923.

Thus, helium with 2 extra-nuclear electrons is a very stable system. The 10 planetary electrons of neon seem to be arranged in two spheres of 2 and 8; argon has three shells of 2, 8, and 8 respectively. As the mass increases beyond argon, Bohr supposes that a group of 18 electrons is pushed in between the two groups of 8; then another group of 18, and finally a group of 32, as shown in the table. The 86 planetary electrons of radon then are arranged in six successive shells. Various attempts have been made to construct a geometrical picture of these shells because of the curiously simple mathematical relations that exist between the atomic numbers of these gases, namely, $2(1^2 + 2^2 + 2^2 + 3^2 + 3^2 + 4^2)$.

Compared with the inert gases, the atoms of all other elements are relatively unstable, presumably because their outer shells are incomplete. Atoms and molecules commonly tend to form combinations in such a way that their outer shells shall have an even number of electrons, especially 8 or a multiple of 8. *They act as if they sought the perfect form of the inert gases. These outer electrons which alone take part in chemical activity are called valence electrons.*

Valence is the measure of an atom's capacity to unite with other atoms to form a molecule. It is measured in terms of electronic charge, with the valence of hydrogen as one. It increases by whole numbers from one to seven, except that two rare elements, osmium and ruthenium, have a valence of eight. No valence greater than eight is known. It is for this reason that Bohr supposes that the number of electrons in the outermost shells of the inert gases (except helium) is eight. Valence is the measure of chemical affinity, and is of fundamental importance in chemical study.

An atom may complete its orbit in one of three ways: by losing electrons (positive valence), by taking on electrons (negative valence), or by sharing electrons with other atoms (co-valence). Thus, when sodium is put in water, its single outer electron is violently pulled off by positive hydrogen ions to form molecules of hydrogen gas. Lithium, with an atomic number one greater than helium, has an outer shell containing one electron. Fluorine, on the other hand, with an atomic number one less than neon, needs one electron to complete its outer shell. In consequence, when lithium and fluorine are brought together under proper conditions, lithium fluoride is readily formed. Lithium is said to have a positive valence of one, and fluorine a negative valence of one. In a completed molecule the positive and negative valences are equal in number. Again, hydrogen has one electron to spare, while chlorine lacks one; therefore, they readily unite to form a molecule of hydrochloric acid.

Oxygen, with six outer electrons, shows a strong tendency to capture or unite with an atom having two outer electrons, or with two one-valence

atoms, and thus to form a stable octet; it has a negative valence of two. Thus, in exploding with hydrogen, one atom of oxygen combines with two atoms of hydrogen to form water. Sodium nitrate, $NaNO_3$, is a more complex substance having a triple octet; its elements have the following valence electrons: $1 + 5 + 6 \times 3 = 24 = 8 \times 3$. Valence two of carbon is explained by its extraordinary power to combine with itself. Some atoms sometimes show experimental valences which diverge from the ideal scheme demanded by atomic theory; when they cannot obtain their ideal complements, they seem content with less.

Since chemical activity depends upon valence, elements with the same valence might be expected to show similar properties. This is precisely what the periodic table proves. For example, the group of alkali metals, lithium, sodium, potassium, rubidium, and caesium, all with a valence of one, are much alike. They are exceedingly active, decompose water, and form many salts; they also form various alkaline substances that are easily ionized. When element number 87 is discovered, it will undoubtedly be an alkali metal resembling the above elements.

It is important to note that some of the physical properties of the elements vary in a linear rather than a periodic manner. For example, the lighter the atom the longer are the waves of its X-ray spectrum. So regular is this increase that the ordinal series of the elements has been strongly confirmed, and the gaps in the series located with certainty.

20. The Branches of Chemistry

The vast field of chemistry is conveniently divided into four great sections as follows:

a. Inorganic or theoretical chemistry is concerned with the systematic description and classification of the chemical elements and of all their compounds except those that contain carbon. It deals with such general problems as atomic weights, valence, and the laws of chemical combination. An important subdivision is *mineralogical chemistry.*

Analytical chemistry is not logically coördinate with the four branches here considered. It is rather the name for an *ensemble* of technical methods which may be applied in any of the other fields.

b. Organic chemistry is a systematic study of the compounds of carbon (*e.g.* sugars, fatty acids, alcohols, and starches). This remarkable element forms more compounds than all other elements combined; more than 200,000 are now known, and others are being discovered every year. Carbon is a constituent of all living organisms; *biochemistry* or *physiological chemistry,* therefore, is an important subdivision of organic chemistry.

c. Physical chemistry makes extensive use of such physical apparatus as the thermometer, electric battery and furnace, spectroscope, and microscope. It aims to determine by precise measurements such physical properties of specific substances as boiling points, crystalline habits, heat and energy changes, laws of liquefaction and other laws of gases. It includes *electrochemistry, photochemistry,* and *radiochemistry.*

d. Applied or technical chemistry may be divided into many specialized branches. The following three divisions may suggest the multifarious ramifications of chemistry into everyday life and some of the extensive industries of today which depend upon chemical knowledge.

1. *Industrial and engineering chemistry:*
   metallurgy (steel, tin, aluminum, copper, alloys, etc.);
   cement and other building materials; asphalt;
   paints and varnishes; inks; paper;
   gas, petroleum, and other fuel and light requisites; lubricants; matches;
   water supply, sewerage, and sanitation;
   food preservation, including refrigeration;
   sugar, starch, beverages, vitamins, and other foodstuffs;
   fats, oils, and soaps;
   leather and tanning; rubber;
   glass and clay products;
   textiles and dyes; explosives; etc.
2. *Agricultural chemistry* is concerned with soils, fertilizers, and the control of insects.
3. *Pharmaceutical chemistry* is concerned with drugs and medicines.

21. Some Characteristic Methods of Natural Science

The chief methods of procedure in natural science may be summarized in the following manner. (*a*) *Natural science rests upon experimental observation and precise measurement.* Contemporary science would be impossible without refined clocks, thermometers, scales, microscopes, telescopes, and other instruments of precision.

(*b*) *The natural scientist aims at describing observed phenomena in generalizations which shall be as simple, comprehensive, and well organized as possible.* The great advances in natural science have been due to the discovery of principles which unify wider ranges of data than any preceding principle. Examples other than Copernicus and Newton are numerous. In 1873 Maxwell published his hypothesis that light waves and electromagnetic waves are identical. At the end of the nineteenth century, light, electricity, heat, and matter were all coördinated in the electronic theory of matter. Notable examples of scientific organization are found in the solar system of astronomy, the periodic table of chemical elements,

the orderly evolution of living things as exhibited in biology, and the vast cosmological system of Einstein.

(*c*) *The natural scientist has made extensive use of various geometrical or mechanical models to aid the mind in picturing and explaining principles.* Examples of these are: the celestial sphere in astronomy, the parallelogram of forces in physics, and the diagrams of molecular structure in chemistry.[39] Some relativists have sought to picture the cosmos as a cylinder in which the three dimensions of space somehow squirm and climb around a central core of time.

(*d*) No intellectual construction, however, surpasses the mathematical formula as a precise and convenient basis for description and prediction. For this reason *the natural scientist reduces his results as far as possible to mathematical symbols.* It was only when Maxwell applied mathematical analysis to Faraday's experimental ideas that he discovered the kinship between light and electricity. Mathematics remains the most powerful tool yet devised for the interpretation of natural phenomena. In the mathematical method and spirit, the several divisions of physical science, as well as those of philosophy and art, possess a strong bond of union.

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CHAPTER IV

BIOLOGICAL SCIENCE

1. Introductory

Biology is an ancient science; yet its contemporary importance is so great that no education is complete without some knowledge of it. The purpose of this chapter is to review briefly such basic notions and laws of this science as are indispensable to an understanding of its scope and function in the general field of human knowledge. The importance of biology has increased tremendously since 1850, and in the past generation it has enjoyed a prestige second to no other science. As a result of this recent development, its assumptions and conclusions have affected almost all other departments of knowledge so profoundly that contemporary thought, as a whole, has a pronounced biological flavor. We are in the grip of biological categories; we think in terms of "structure," "function," "organism," "environment," and "evolution" with an ease which is none the less assured because of its newness in our civilization. Lying, as it does, at the base of that pyramid of knowledge which concerns the human species, biology furnishes generalizations which reach in their significance throughout the whole of the realms of psychology and social science. Human thought and conduct, human nature and its possibilities, can be fruitfully approached *via* biological paths; hence the utilization of biological notions. Much of the avidity with which recent biological conclusions have been used may be due to the dramatic character of their development and the desire to apply in other fields a point of view which has been so magnificently fruitful in biology. A certain haste is inevitable and some conclusions may prove sterile. Indeed, many are. But the bulk of recent biological knowledge is both sound and usable and constitutes no inconsiderable part of that phenomenal growth of our culture which we discussed in Chapter I.

2. The General Field of Biological Science

Biology may be defined etymologically as the "science of life" (from the Greek Βίος = "life") or, more specifically, as the group of disciplines having to do with the description and classification of living things, their origins and developments, their structures and functions. It is familiarly

divided into zoölogy, which deals with animals, and botany, the study of plant life. Specialized branches, such as bacteriology and entomology, are then distinguished as sub-sciences. Another grouping of the materials of biological science is possible along the lines of certain fundamental viewpoints for studying living things: (*a*) *taxonomy,* or systematic biology, which aims at classifying living organisms; (*b*) *morphology,* the study of the structures, or forms, of life; (*c*) *physiology,* the science of functions and processes; and (*d*) *genetics,* the science of origins. Whatever may be the divisions of material which the particular biologist may favor, the methods which he employs are similar to those of every other biologist, and all of them are aimed at illuminating the events called *life.* Description and classification have been generally characteristic of biological methods since Greek times; careful observations, wide comparisons, and methodical groupings of material result in the distinction of general types, of phyla, and of various species. Instruments, such as the microscope, aid the minute analysis involved in careful study of structures, and experimentation with living functions is carried out as systematically as possible. Even statistics (called, in biological use, "biometrics") plays its part in the methods of biology, notably in the measurement of heredity traits and in economic biology.

3. The Powers of Protoplasm

How does organic matter differ from inorganic matter? This is a question which cannot be answered fully by either physical description or chemical analysis. The very answer to the question generates a science of a different sort from those discussed in the previous chapter. Chemical analysis may bring to light the fact that relatively few chemicals can combine into the living partnership of elements called protoplasm; these include carbon, hydrogen, oxygen, sulphur, chlorine, potassium, magnesium, iron, nitrogen, sodium, and a few others. Beyond this the physical sciences, as a whole, can tell us very little. Organic stuff, or protoplasm, is a colloidal mixture, usually glue-like in texture, but varying with conditions from a thin, watery liquid to an almost solid, gelatinous material. Protoplasmic colloids belong to a group which biochemists call emulsoids, and these have physical properties characteristic of living matter. But protoplasm eludes the science of chemistry in spite of the fact that it contains no unique chemical element and that all elements found in it are found, and may be studied, also in an inorganic condition. Rather should we say it is because the same elements *in the same ascertainable combination* may or may not be living that protoplasm eludes the science of chemistry.

When protoplasm is killed, its weight is not changed. The lifeless remains weigh the same as the moving organism, and its chemical constit-

uents are identical. The differentia of protoplasm is not, therefore, some peculiar substance or combination of substances acting in accordance with the laws of physics and chemistry. The differentia is the *activity* which goes on. Matter as it merely falls, or is dislocated in position, is studied by physics; in its constituent elements and their reactions upon each other, it is described by chemistry. But when matter not only falls or is dislocated, when it not only reacts and recombines, but also grows and reproduces, is irritable and adaptable, it is called protoplasm. These functions are more restricted in scope than the activities studied by physics and chemistry; and they are more exclusive. So far as we can ascertain, these life activities are derivable at present only from previous protoplasm possessed of the same functions. Once the thread of continuity is snapped, the loss is irretrievable. We cannot manufacture life by any known process of chemical synthesis. Life is unique, and the laws and concepts of biology are our ways of stating that uniqueness. The rich qualitative differentiations of activity with which biology concerns itself entirely escape the gross quantitative techniques for measuring the attractions and repulsions of matter so carefully catalogued by physics. The laws of motion and the law of the conservation of energy furnish no aid in describing reproduction; mechanics provides no account of the origin of species. With life, matter enters a new dimension and new terms are necessary to describe its career.

Protoplasm is the inclusive term used to designate all living substances. It invariably contains materials called proteids, and *it has the capacity of producing them out of other substances.* Furthermore, protoplasm *maintains itself and increases, " grows " we say, by intussusception* rather than by accretion. Other chemical substances increase in size by additions to their bulk, as in the case of the growth of crystals. But living matter alone takes in new particles and fits them into the interstices of its bulk, replacing broken-down materials or increasing the amounts already there. Most remarkable of all, protoplasm is *capable of reproducing itself.* The organism produces another identical structure — not numerically identical, of course, but identical in kind.

The remarkable character of these powers of protoplasm is well illustrated by contrasting an airplane and a bird. If an airplane flew itself, replaced its own worn parts, occasionally detached from itself some bit of wood or metal which grew up shortly into another airplane with similar powers, it would resemble the bird in its activities and could be classed as protoplasm. But it does none of these things; nor does any inorganic material do them.

4. The Cell Theory

Protoplasm always exists in very small definite units called cells. The cell is the universal unit of vital structure; and the biological science named morphology, with its sub-sciences cytology, histology, and anatomy, studies the multiform appearance of protoplasm in the cell itself, in tissues and similar aggregates of cells, and in grosser organizations of living matter which may be dissected.

The theory of the cell was not worked out until the development of the miscroscope, and cells, therefore, were not seen until the modern period. Robert Hooke (1635–1703) in his *Micrographia,* published in 1664, described the regular arrangement of the compartments in cork and, since they resembled the cells in a monastery, suggested the term. But the theory that the cell was the unit of structure and function, the *living atom* so to speak, was first enunciated systematically in 1838–1839 by M. J. Schleiden (1804–1881) and T. Schwann (1810–1882).[1] Since then the cell has been regarded as the key to all biological problems.

The cell theory brings all botanical and zoölogical problems together under one point of view by revealing the common plan of organization. By focusing attention upon the cell, the theory made possible rapid strides in the knowledge of embryological development.[2] Furthermore, all the various functions of the human body, all the activities studied by both physiology and pathology,[3] came to be regarded as visible manifestations of movements pivoting within the cell. Finally, the cell theory was instrumental in the solution of the age-old problem of the fertilization of the egg and the mechanism of biological inheritance. The cell theory must be recognized, consequently, as a biological generalization of an importance second only to that of the theory of evolution. It is worth while to know the typical structure of cells. The diagram on opposite page, from E. B. Wilson's *The Cell in Development and Heredity,*[4] is a composite picture of their generalized features. The nucleus of the cell always contains chromatin, which is the material in germ cells concerned with the transmission of hereditary traits. Taken together, the other parts of the cell, about some of which we know little, are called the cytoplasm.

[1] Schwann, Theodor, *Microsocopical Researches,* Berlin, 1839. Schwann is usually regarded as the founder of the cell theory.

[2] *E.g.,* Kolliker, R. A. von, *Handbuch der Gewebelehre des Menschen,* 1852; *Entwickelungsgeschichte des Menschen,* 1861.

[3] Virchow, R. (1821–1902) is called the founder of cellular pathology.

[4] Wilson, E. B., *The Cell in Development and Heredity* (3d ed.), New York, Macmillan, 1925.

5. Evolution

The most important generalization in biological science is the doctrine of evolution. This is a statement of the manner in which the existing species of living organisms developed from previous forms of life. Although general developmental theories have been popular since ancient days, the formulation of a specific verifiable law of the mutation of living forms was left for the latter part of the nineteenth century. Charles Darwin (1809–

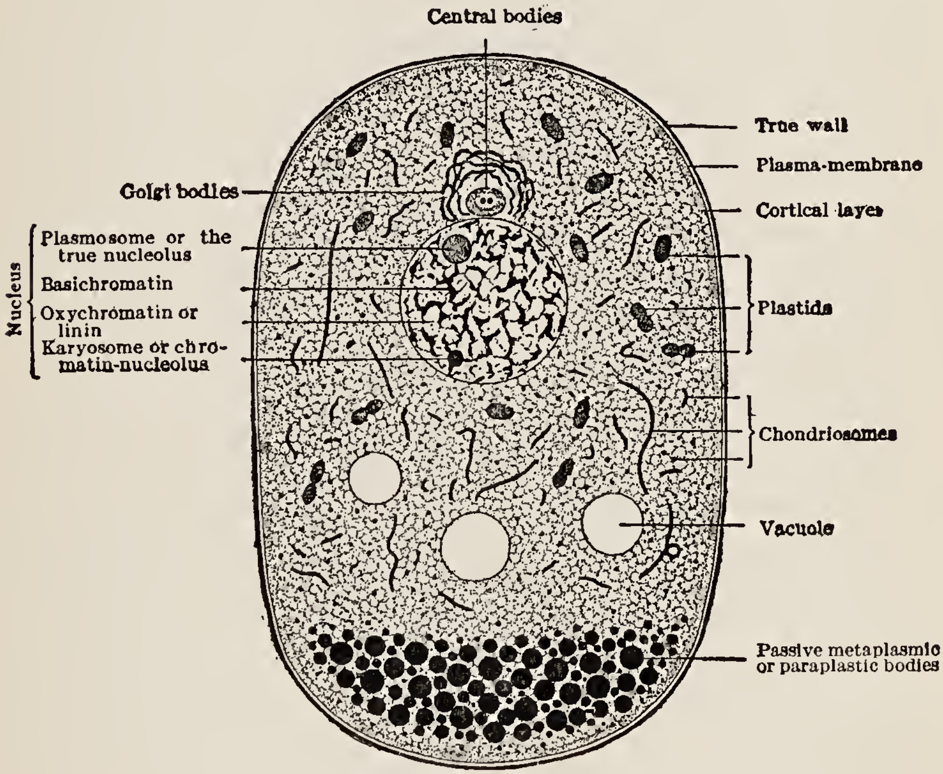

Fig. 7. General Structure of a Cell

(From E. B. Wilson, *The Cell in Development and Heredity,* Third Edition. Copyright 1925 by the Macmillan Company. Reprinted by permission.)

1882) and Alfred Russel Wallace (1822–1913), working simultaneously, brought forth the natural selection theory which is associated with Darwin's name and which Herbert Spencer (1820–1903), Thomas H. Huxley (1825–1895), and many others, helped to popularize in various modified forms. Darwin's *Origin of Species,* published in 1859, was an epoch-making work. Thomas R. Malthus (1766–1834) had previously shown, in his works on population,[5] that enormous overproduction existed. This overproduction of posterity was so great that unless living things perished in

[5] Malthus, T. R., *Principle of Population,* 1798; *Essay on Population,* 1803.

vast numbers before maturity, the earth soon would be covered with a thick coating of living forms. Darwin could have taken his suggestion from sources other than Malthus. The prevailing idea, derived from the optimism of the eighteenth century, was that nature worked for the best, although specific individuals might not. With Malthus this took the form of explaining how vice and crime kept the human population from becoming too large. At all events, Darwin saw that in the competition for survival of hordes upon hordes of animals lay an important key to the explanation of the alteration of living forms. All animals are not alike; wide divergencies exist within each species. Now, said Darwin, some of these variations are better fitted to the environment than others, and the animals possessing them can compete successfully in the struggle for existence. Those animals which have some definite trait preventing survival are eliminated, and the development of the particular species follows the variations which are thus selected by the environment. In Darwin's theory the process of evolution involved in some form the following phases: (1) overproduction with variation of forms; (2) the struggle for existence; (3) the elimination of the unfit; and (4) the emergence of a new species.

If by the phrase "the Darwinian theory" we mean the general biological doctrines concerning the development of new species out of previously existing types, then the theory is more strongly intrenched in scientific thought today than ever before. But if we mean by the phrase the specific points made by Darwin in his writings on the subject of evolution, then we must say that the development is not so simple a process as Darwin thought. Darwin's essential contribution lay in his stating the factor of *natural selection* with such vividness and force that, once and for all, the environment was recognized as having something essential to do with the forms of life.

(*a*) Evidences of Evolution. — Although the exact definition of all the factors involved in the phantasmagorical changes of living species is beyond the reach of our contemporary knowledge, the fact that all species are related, and that all have come from previously existing types, is accepted without question. The evidence is overwhelming and can, for the most part, be grouped under four heads:

1. *Paleontological evidence:* fossil remains indicating previous forms of present species and the various forms of extinct species. Much of this is what is expected, given the theory of evolution. Fossil forms are found, which have traits now possessed by widely differing species. When this occurs, their common ancestor, or at least a connecting development, is probably under observation. The history of the crocodile, the elephant, and the horse are very convincing. The present horse came from a

quadruped about 12 inches high and weighing 60 pounds, having four toes, and the vestige of a fifth in the skeletal splint. The fossil series of cuttlefishes is, perhaps, as striking an example as can be mentioned. The whole history of the species, as built up out of the legends in the rocks — fishes before amphibians, amphibians before reptiles, reptiles before birds, birds before mammals — is a solid mass of evidence which suggests only one hypothesis: the doctrine of evolution.

2. *Embryological evidence* is just as conclusive. Invariably the embryo in its development passes through more primitive stages of living form. Beginning with simple cells it differentiates rapidly into the complex structures exhibited by the newly born young. Mammals, for example, at a certain stage show gill clefts reminiscent of aquatic ancestors. Indeed, the story of the evolution of any specific organ of a species might be traced by embryological analysis, were it not for the skips which occur. Steps drop out in the embryological account which an animal writes of its past, as though the species had forgotten a chapter in its autobiography, or made a better story by suppressing part of its past history. Undoubtedly there are chapters which any species, if it had a memory, would be glad to forget! With all the omissions, however, the evidence is still in one direction only. The chapters, such as they are, are never reversed.

3. *The morphological evidences* are as good as those already mentioned. The relatedness of species varying widely in appearance is revealed upon the dissecting boards of the anatomist. The whale, for example, has all the structures of the hind leg of all mammalian types represented only internally (albeit they are suppressed entirely in some species) with very minute structures. But the arm, used as a fin, retains all the structures of shoulder, forearm, hand, etc., enclosed in a finny sack useful in swimming, but useless for other purposes. The head retains the bones of the skull, sutures and all, stream-lined after the manner of aquatic life. In short, the structures are those of all mammals, and the relatedness is incontrovertible. But those structures have been tortured and twisted into their present shapes to serve the purposes of a submarine existence. The bat has the same arm, and is a mammal, but uses the hand, with greatly lengthened fingers and a connecting membrane, as a means of flying. However disparate the functions which may be performed, the racial relatedness of species is apparent to the morphologist in the homology of structures. Where the same structure reveals itself, however widely differing the activities, a continuity of descent is indicated.

4. Another mass of evidence may be called *genetic* in character. Numerous variations are taking place contemporaneously, many of them among domesticated animals and plants. Alterations of existing species of wheat and oranges, as well as of hogs and bulldogs, indicate

the efficacy of artificial selection. Evolution is observable *in process,* both with natural selection operative and subject to the controls of man.

The doctrine of evolution passes all scientific tests which are imposed upon it. In terms of the scientific criteria of predictability and control, the theory is as well verified as any other theory concerning living things. It is one of the great foci of contemporary thought. To deny biology the use of the evolutionary theory would reduce it at once to a medieval scientific chaos.

The specific features of the contemporary doctrine of evolution are not so easy to trace as are its general outlines. We can approach it best, perhaps, by a consideration of three of its aspects: *heredity* (the factor of stability), *variation* (the change factor), and *selection* (the elimination by the environment).

(*b*) Heredity. — A discussion of the question of heredity indicates at once how far contemporary thought is removed from Darwin. The notion of pangenesis, suggested by Darwin [6] in 1868 (as well as the physiological unit theory proposed five years earlier by Herbert Spencer), is no longer seriously considered. Darwin held a theory that the cells of a body budded or proliferated, producing minute gemmules which were diffused throughout the organism, and possessed the properties which the original material had when they were thrown off. Under conditions of reproduction these gemmules gave rise, according to the theory, to the same kind of cells as those from which they were derived. To use his own words, " ovules, spermatozoa, and pollen-grains — the fertilized egg or seed, as well as buds — include and consist of a multitude of germs thrown off from each separate part or unit." This made, of course, both hereditary stability and variation a function of individual somatic traits.

August Weismann, in 1883, challenged this and other theories involving somatic features directly in the transmission of hereditary traits, by his famous " germ-plasm " theory, which speculatively anticipated surprisingly well the direction which subsequent investigation was to take. His notion was that the cells having to do with reproduction, called by him the germ plasm, were unbroken in continuity, and produced around themselves in each generation a body plasm which served as a temporary habitat. This germ plasm itself he thought of as immortal, although the body which carries it dies. The body is unable to affect the germ plasm, for better or for worse; the cells which carry the traits of the species are not altered by any somatic changes whatsoever. Determiners (or *ids,* as he called them) within the germ plasm occasion the repetition, in each successive body which it grows about it, of the same stock of traits.

[6] Darwin, C., *Variation of Plants and Animals,* Vol. II, p. 350.

Weismann thus denied categorically the inheritance of acquired characteristics, and it is now almost universally conceded among biologists that no satisfactory evidence in support of that doctrine has ever been presented.

Johann Gregor Mendel (1822–1884) was an Austrian monk, abbot of the Augustinians at Brünn, who became interested in the hybridization of various varieties of peas. In 1865 he read a paper before a local scientific society on the subject of plant hybridization.[7] The work of Mendel came before the germ plasm theory, but it fitted well with the notion of a continuous mechanism of heredity which combined and recombined according to its own laws, irrespective of environmental alterations. Not until 1900 was the importance of his work recognized; and its rediscovery aided greatly the development of the study of genetics. During recent years a great amount of research has been devoted to the maturation of the egg and sperm cell and a considerable body of knowledge has been built up concerning the mechanism of heredity, explaining the relations detected by Mendel, as well as others. Mendel came to the conclusion that the individual is not the unit of heredity, but that each individual is composed of many unit characters which may be inherited and transmitted in various combinations. The regularities which he observed in the transmission of characters are called Mendel's laws. Each trait, said Mendel, is a doublet; for example, each individual receives an hereditary influence from each parent for eye-color. Traits which always appear when present in the hereditary strains he called "dominant." A trait which disappears in the presence of its opposite is "recessive." So, in the case of eye-color, darkness is dominant and lightness is recessive. The hereditary influence is now definitely associated with the chromosomes within the nuclei of the cells having to do with reproduction. In the process of the segregation of the egg and sperm cells, the chromosomes are reduced to half the number in the typical body cell of the prospective parent; otherwise each offspring would have twice the number of chromosomes possessed by either of its parents. Each parent contributes to the hereditary stock of the new individual only one half of the number of chromosomes which were derived by it from the previous generation. To illustrate, let us suppose that eye-color be traced through several generations, beginning with a pure dark and a pure light. Each individual is double and appears as such in the accompanying Figure 8. All the offspring will have one dark and one light determiner in their chromatin material, and their eyes will be dark in appearance. This is Mendel's "law of dominance"; a trait so appearing in the presence of its opposite is dominant. But these offspring are not pure for the trait. They are hybrid, and if we go to the next generation with them

[7] Mendel, J. G., *Versuche über Pflanzenhybriden.*

we get an entirely different result. The second generation, Figure 9 (F_2 is the symbol used universally to represent it), will appear in the ratio of one pure dark, two hybrid dark, one pure light. The pure dark and pure light are called " extracted " pures and will breed true. The hybrids are, of

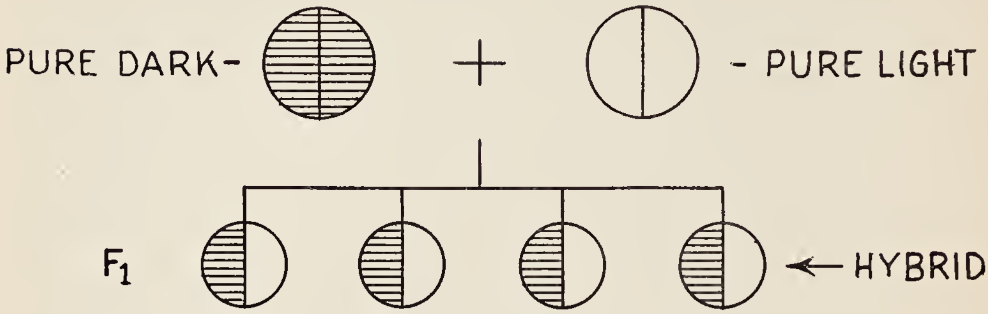

FIG. 8. MENDEL'S LAW OF DOMINANCE

course, similar to their parents. In appearance the ratio is three darks to one light. This illustrates Mendel's " law of segregation " or " law of the splitting of hybrids." The exact ratios are not obtained unless a large number of offspring are noted, but in the generations observed by Mendel

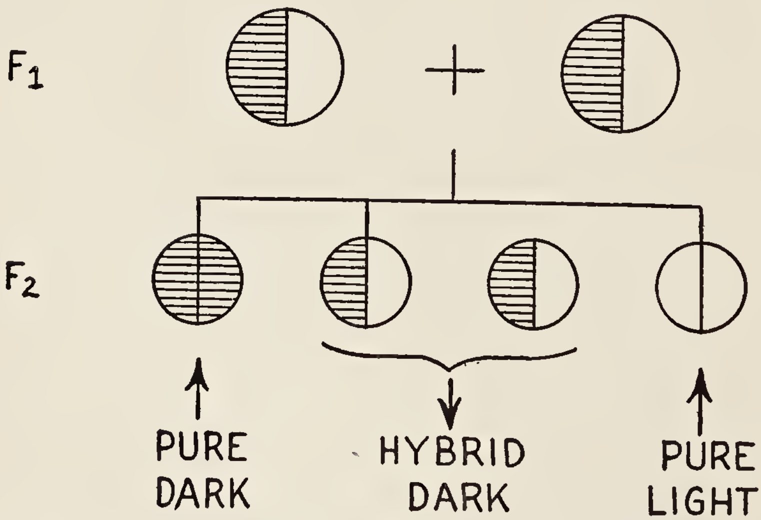

FIG. 9. MENDEL'S LAW OF THE SPLITTING OF HYBRIDS

a sufficient observation was made to enable him to state the law that the second generation shows three dominants to one recessive.

If we take two traits such as blackness and whiteness of fur in guinea pigs, black being dominant, with smoothness and roughness of coat, with

roughness dominant, and follow them through the F_2 generation we get characteristic results of a more complex sort. Capital letters in the accompanying Figure 10 represent dominant traits and small letters indicate the recessive ones. If we add another pair of characters, the possibilities of combination are again doubled. In animals which have many traits the possibilities run into the millions. Here, obviously, is a mechanism which can be used to explain a large number of the variations noticed from genera-

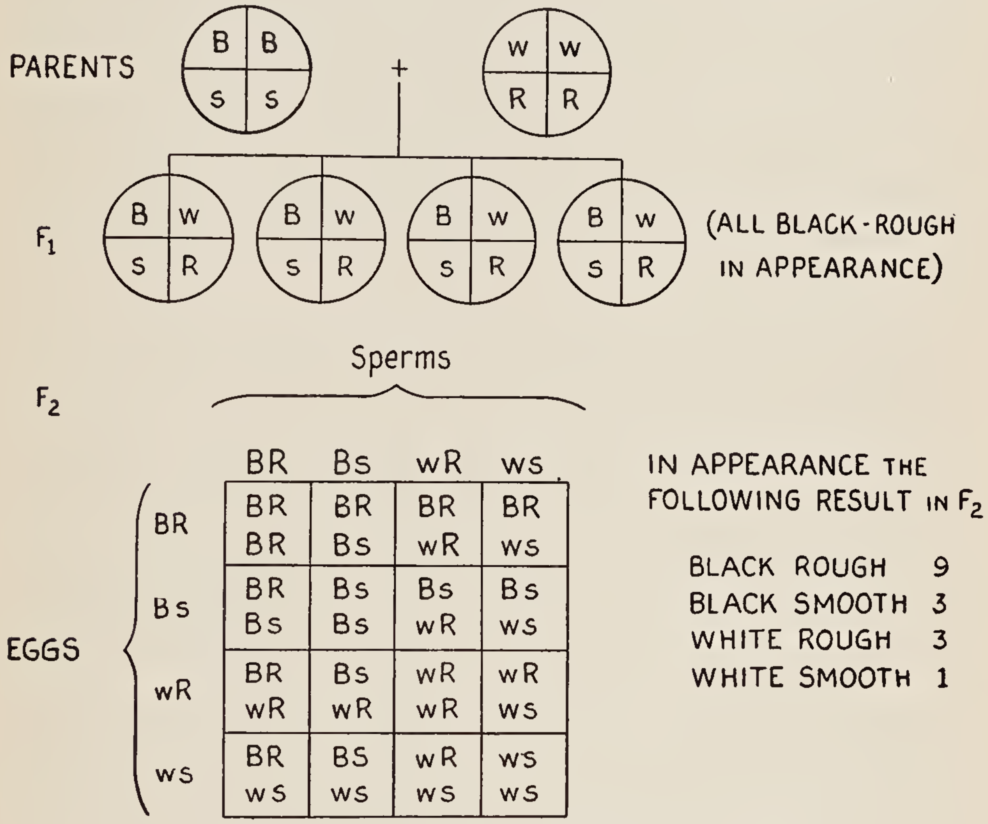

Fig. 10. Mendel's Laws Illustrated by Two Traits

tion to generation; and the theory meets the scientific tests of predictability and control through prediction.

(*c*) Variation. — But what is the source of *novelty*, of genuinely new traits? No matter, one may say, if heredity does combine and recombine; how can the shuffling of a deck of cards produce a new and different card? One may get novel hands in cards, of course; and novel combinations of hereditary traits are produced by artificial selection in breeding, as well as in nature. But *new traits* come in also, and these become part of the transmissible hereditary character. This question is one of the most difficult which biology confronts. Obviously, if all the members of a species were forever identical in their characteristics, the environment might vary

indefinitely and no change would take place, excepting possible extinction of the species in the event of an environment too inimical in character. Faced with this problem of variation biologists have split into various camps. (1) There are those who maintain, following Lamarck (1744–1829), that variations are the result of environmental habituations; that acquired characteristics are inherited, and that effort and will, therefore, play a part in effecting the alteration of species. (2) A second variety of theory bases itself on Mendel's laws of heredity and refuses to regard variation as anything other than the result of the hybridization of species. (3) A third group follows the theory of minute fortuitous alterations within the germ plasm — chromosomal aberrations and gene mutations — for positive variations, at the same time admitting that environmental conditions radical enough to affect the blood stream may so alter the chromosomes as to produce transmissible defects.[8] This is the orthodox theory among biologists.

It is evident that the whole account of the combination of chromosomes and genes within the germ plasm, *i.e.*, of the mechanism of heredity, must be added to the earlier evolutionary theories. We know that the chromosomes within the nuclei of the sperm and egg cells contain determiners, or "genes," as they are called. These genes are strung along within the chromosomes like peas in a pod, or beads on a string. The chromosomes as a whole are shuffled and redealt each generation according to the Mendelian laws, as we have seen, but accidental twistings and shiftings of these organized materials occasionally take place, resulting in additional (double or triple) chromosomes in some individuals, and in "crossing-over" (or interchange of genes) in others. There are various possible types of failure to segregate or to combine properly. Variations in the visible adult forms of a species may arise, consequently, from chance combinations (violating the Mendelian laws), linkages, etc., at the level of the chromosome. But, in addition, gene changes occur within the chromosomes. That is, the determiners (genes) within a chromosome may reach a new chemical equilibrium spontaneously, and a "mutant" character will therefore result. This is a second level of chance alteration, so to speak, although these mutants may show a certain order, indicating that other constant relations are there to be subsequently discovered. The fact is that very little is known exactly about the causes of these chemical shiftings which are the basis of mutations. To attempt to give the *causes* of an *accident* sounds like an impossible task; the *mechanism of fortuitous change* sounds like a contradiction in terms. But the importance of these minute varia-

[8] *Cf.* Newman, H. H., *The Nature of the World and of Man,* University of Chicago Press, 1926, p. 401. *Cf.* The writings of Jennings, H. S., Morgan, T. H., and Müller, H. J.

tions is such that biologists will return again and again to the task of observing and analyzing them within the background of the infinite detail of living activities. What seems an accident in terms of the Mendelian theory may seem necessary in terms of another notion; and many notions are required to enable us to control so complex a thing as life.

It should be added that all alterations in transmissible traits by environmental influences which are proved seem *negative* rather than positive in character. The new method of irradiation by X-rays has demonstrably modified the mechanism of inheritance, both by way of aberrant distribution of chromosomes and by gene mutations, so as to produce inheritable variations in some instances. In recent experiments on *Drosophila,* heavy irradiation increased the number of mutations by thousands of per cent. Transmissible changes can be produced by means environmental (though not Lamarckian) in character, but that these alterations are other than *injuries* remains to be demonstrated.

(*d*) Selection. — But there is the other side of the problem of evolution, the side emphasized by Darwin. In addition to the intrinsic factors, *heredity* in its regular functioning, and *variation,* there is the question of the extrinsic relation of the species to its environment. Here the negative operation of natural selection comes in. A species may hybridize and vary as chance or necessity decrees, but whether its variant or novel forms can continue depends on exterior conditions. The germ plasm proposes and the environment disposes.

The wide variety of differing species is undoubtedly due in part to the wide dispersion of variant strains of hereditary traits. A species might vary and spread into various climates. Certain geographical locations might eliminate some strands of tendency while other environments would cut off different developments. Moreover, a given species may confront various environments simultaneously by virtue of its geographical dispersion, and these environments themselves, though always negative in their selection, may vary. Climate changes, and an animal adjusted to the cool dampness of an ice age might not also be equipped to survive in the sub-tropical jungles of an inter-glacial period. Furthermore, the shifting in the forms or functions of a neighboring species is itself an environmental change for a given species. The possibilities are as indefinite in number here as they are in the field of variation. The resulting forms have given ample evidence of the myriad possibilities of life.

Evolution as a process is to be thought of, therefore, as a dynamic relation between the pulsing, changing types of living things and a shifting, constantly varying environment. A sudden aberration in intrinsic character by a species may be indefinitely tolerated by the environment. Again, a stable adapted type may be ruthlessly exterminated by a sudden change

of environment. Geological history records many alternations of heat and cold, of moisture and aridity, while the history of life is strewn with extinct species. Woe to the animal which, at any time, possesses traits, whether new or old, that prevent its coping with its environment *as that environment then exists!* But, although a species cannot continue to possess traits which occasion its elimination, the fact that a species has a certain trait at any time does not mean that the particular trait has any specific positive survival value, or biological utility, in that environment — nor even in any previous environment. It means merely that the trait is not inimical enough to cause extinction. The tolerancy of the environment is as important, obviously, as its selective action. For by the accumulation of new traits, which are for the time being neutral as regards survival value, eventually a species may develop a trait which gives it greatly superior adjustment to its natural habitat. So long as a species possesses a sufficient stock of characters favorable to survival, it can indefinitely experiment, so to speak, with harmless traits of color, shape, and function. Evolution is not to be thought of as a forced process entirely, therefore, but rather as alternations of leisurely groping and aimless shifting with extreme, bitter, and fatal need. Even the trilobite had its breathing spells, though eventually it became extinct.

The chief error in thinking about biological evolution is likely to be an overemphasis on one factor at the expense of the other. The environment does not do it all; neither does the organism. To read Herbert Spencer's works is to gather the impression that the organism is mere putty in the hands of the environment. Spencer, of course, believed in the inheritance of acquired characteristics, and an overemphasis on the environment is an easy error for this type of view to commit. The vitalists fall into the opposite error. By them the potentialities are read into the organism and evolution then appears as the progressive unfolding of powers already definitely inherent. The French philosopher, Henri Bergson, for example, points out that the function of vision has appeared on the branches of the tree of life *above the point of their separation* and he argues that vision must, therefore, have been inherent in an original vital impulse (*élan vital*), or life itself, below the level of its bifurcation. But this theory simply takes the other horn of the artificial dilemma. Unless there were a visible environment, the visual possibilities of any hypothetical organism would be *nil;* and if there were an environment possessing visibility, what could be more advantageous biologically for an animal than to see it? *Life* is a joint function of organism and environment, the potentialities of which cannot be claimed exclusively for either of the two.

6. The Origin of Life

The beginning of life on the earth is shrouded in mystery. We simply do not know when or how life first appeared, either on the earth or elsewhere. But it is interesting to speculate. In the past, recourse has been had to various sorts of supernatural explanations of the genesis of both inorganic matter and of life — creation stories about various gods, such as Marduk and Yahweh. But these stories have the scientific disadvantage of doubling the problem. The account of exactly how and when life came to be remains to be given, while the supernatural entity is also to be accounted for.

During the nineteenth century several first-rate thinkers suggested that life came to the earth by means of minute living creatures which drifted to our planet on meteors or dust. Some seeds and spores have remarkable ability to endure heats and colds and the absence of oxygen. Helmholtz and Lord Kelvin were among the adherents to this view. The difficulty with it is readily seen. It shifts the problem of the genesis of life from this planet to some other unknown source. How, then, did life originate there? The question still remains.

If we think of life as originating on the earth, the question becomes a scientific problem of determining the conditions under which life came to be. Unless we say that life always existed, a hypothesis seemingly excluded by the theories of astronomy and geology, we must take the position that at some time, or times, it did originate from inorganic sources. There is absolutely no evidence that it is now originating in any part of the world. Spontaneous generation is a defunct theory. But if the genesis of organic from inorganic matter occurred once, it can be made to take place again by the exact duplication of the conditions previously present. On this assumption biochemists will work to ascertain, closer and closer, the exact relation of the organic to the inorganic world. We know that life appeared when the earth was able to support it. To produce life from inorganic matter in the laboratory cannot, therefore, be called an impossibility, in spite of the fact that all the evidence (excepting only this demand made by geological and astronomical theories) indicates that life comes only from previous life. If living forms ever are found originating from the inorganic, or ever are made so to generate in the laboratory, men will feel, perhaps, a greater kinship with the stars and rocks than they now wish to acknowledge. A similar ignorance of the origin of sex prevails, although the theory was advanced a number of years ago that fission among protozoans is the result of the starvation of the parent organism. That is, as the bulk increases more rapidly than the surface, through which feeding takes place, the little animal subdivides to reëstablish a tolerable harmony between its

mass and its rate of nutrition. Fission is reproduction at its lowest level, and this theory, therefore, would regard sex as genetically derivative from nutrition.

7. Biology and Medicine

Medicine is an applied biological science. As such, it offers an excellent illustration of the utilities of modern biology. No better method of presenting the significance of modern biology, in the applied field, can be used than to contrast the techniques of modern medical treatments with those of the ancients.

Physicians in the ancient world knew a considerable amount about the repairing of fractures and concussions. The Egyptians developed splints for broken bones and performed operations upon fractured skulls to remove chips of bone from the brain surfaces. Undoubtedly the working of slaves upon such vast stone edifices as the pyramids provided abundant injured human material upon which to work. The Greeks, availing themselves of earlier materials, developed a medical tradition centering around the figure of Hippocrates (460–377 B.C.?) who has been called the "father of medicine."

But, however much primitive and ancient men knew of mechanical items, such as breaks and fractures, their knowledge of fevers and nervous diseases was grotesque. Almost universally such diseases were attributed to demoniacal powers. All popular ancient literature is saturated with the implicit assumption that demons possessed men and caused them to do strange things and eventually to die. The notion is part and parcel of that primitive animism which saw a dryad in every tree, a god in every stream, and a spirit power in every storm. Demons explained insanity, dreams, crowd hysteria, meteorological events, and the drama of moral choice for the ancient populace, and it is not surprising that fevers, indeed sickness in general, should have been included. The demon was not a major power, it should be observed. He was a small agent who lurked in dark recesses, under objects, around corners, and in unusual places. He was as invisible to the naked eye as is the modern germ. Ancient man took such precautions against him as he could. However, instead of using individual drinking cups, towels, and antiseptic solutions by way of insulating himself from infections and contagions, ancient man relied on incantations and carried charms and amulets. He placated by magical means, and warded off by necromancy, these mischievous invisible miscreants of the spirit world. When, nevertheless, a demon took possession of some unfortunate human, cajoling or cursing might be employed. The physician might plead with the demon or swear at him with all the powerful language he could muster. Frequently recourse was had to more violent tactics in order to shake

loose the demon's hold upon the luckless mortal. Smudging and beating were common treatments. In the hope that the demon would be discouraged from remaining, the poor victim would be put into a small pen and a dense smoke produced under him until he was almost asphyxiated. But the treatment might not stop at smudging or beating. Trepanning was also resorted to in terms of this theory of demons. A continuous pain in the head might be treated by the removal of a piece of the skull about the size of a half-dollar, in order to let out the demon. The same method was applied to the joints. Acute pains in the knees might be followed by a drilling of the knee-caps to let the demon escape. When medical science was in such a state as the foregoing indicates, the sick had little chance. If the disease did not kill them, the cure of it did! The literature of the Middle Ages provides many pitiful accounts of the atrocities suffered by sick and abnormal folk at the hands of their well-meaning but stupid contemporaries. The witchcraft craze of Salem, Massachusetts, indicates that demons were very tenacious historically. Indeed, modern and contemporary spiritism is the belief in demons as the cause of disease, surviving in the sphere of nervous diseases.

Contrast with this the modern science of bacteriology as utilized both in medicine and in surgery. Although smallpox was mastered by Jenner, who published his experiments in 1798, by a purely empirical study of cowpox and the observation that milkmaids who had taken this disease were immune to the human form of the ailment, an extensive control over the ravages of parasitic bacteria awaited the development of a scientific account of their life habits. The lateness of this knowledge is astonishing. Many of the commonplace precautions of surgery and the techniques of inoculation in medicine are as recent as radio. The medical men of 1850 were ignoramuses. In their knowledge these men resembled our contemporary surgeons as little as the astrologers of ancient Alexandria resembled Sir Isaac Newton. But they were the professional forbears of our present medical men; and it was largely their own efforts which effected the change.

In 1876 Robert Koch (1843–1910) published a paper on the *Aetiology of Anthrax* which was an epoch-making work.[9] The work of Antony Leeuwenhoek (1632–1723) and of Lazzara Spallanzani (1729–1799) had laid the basis for a fruitful study of microörganic life, but the significance of their work had been both conjectural and very narrowly appreciated. Koch proved conclusively, to the satisfaction of the entire intellectual class, that anthrax was caused by a germ, too minute to be visible to the naked eye, which got into the blood of men and animals and fatally choked

[9] *Cf.* de Kruif, Paul, *Microbe Hunters,* Ch. 4, New York, Harcourt, Brace, 1926. This book is a vivid history of bacteriology.

the bloodstream into a black and gluey mass. He traced the life history of this germ and told the cattlemen of Europe how their beautiful pastures became deadly to uninfected cattle who grazed upon them. His *Aetiology of Wound Infections* in 1878, his studies on tuberculosis (1882), and Asiatic cholera (1883) are equally dramatic chapters in the conquest of microörganisms.

Louis Pasteur (1822–1895), whose microscopic work on fermentations and on hydrophobia (culminating in inoculations for this disease in 1885) were as epochal as the researches of Koch, stands with the latter at the head of a long line of scientific workers who have revolutionized medicine and surgery. Instead of operating with dirty knives and under unclean conditions, surgeons like Lister (1827–1912) began to use *antiseptic* methods. Knives were washed, wounds were treated with chemical solutions which prevented the development of microörganic life, and deaths from wound infection and child-bed fever immediately decreased in number. Finally *aseptic* methods came in. Not only clean instruments but also clean air was demanded and the atmosphere of the modern operating room is as nearly sterile as contemporary filtering ventilators make possible.

Surgeons do not aim today to keep down infections by antiseptics but to keep them out altogether by providing an absolutely clean environment for their patients. In medicine, the results of bacteriological research have been equally gratifying. Typhoid fever, diphtheria, tetanus, pneumonia, tuberculosis, yellow fever, malaria, and the venereal diseases have been controlled in a way impossible before the knowledge of parasitic microbes was acquired. The progress of medicine and surgery in the last fifty years reads like a fairy story, and the power which has lengthened the life-span of man from less than thirty years to an expectancy of fifty-eight years is a direct function of biological science.

The bearing of biological science upon human affairs is not limited, however, to medical and surgical matters. Biology helps us to handle our domesticated plants and animals. It tells us not only how to breed them for the traits we want but also how to protect them from their respective parasites. Furthermore, biology helps us to write our own history. The preface to the science of human history is furnished by anthropology, a discipline which attempts to describe the development of primitive man in terms which are evolutionary. Biology is also of fundamental importance in psychological science, and, through this, exerts a controlling influence on the social sciences.

8. Biology and Psychology

Biology throws light on psychological problems in a large number of ways. The biological nature of man, which shares its basic functions with other living things, is studied in physiology and morphology. The development of the evolutionary approach to living things has, consequently, revolutionized psychology. Man is now an " organism " in an " environment." His sense organs, as well as other organs, have come to be as a result of a long process of " variation " and " selection." His higher neuronic processes also are treated by biological methods. Intelligence is a " selective " agency, a subtle process of " adjustment." A thorough understanding of psychology today is impossible without some specific knowledge of nervous anatomy and physiology and a general grounding in the basic assumptions of modern biology. Many of the stock problems of contemporary psychology, such as the nature of instinct and emotion, are as much biological as psychological in character.

One of the more recent contributions of biological science to the understanding of our conscious life and the interpretation of thought and character is the new knowledge concerning the place of the ductless glands in the economy of our human systems. This knowledge comes directly from physiology to psychology, and a glance at some of it will indicate its importance.

All glands are classed under two heads: (1) those with ducts (salivary glands, sweat glands, stomach glands, etc.) and (2) ductless glands, also called endocrine glands, which discharge their materials directly into the blood. The part the latter play in our life processes is just coming to light. The *pituitary gland,* located at the base of the brain, if functioning excessively, produces a large, even giant, skeletal growth. If deficient, growth is retarded, sexual development inhibited, and obesity produced. Removal of the gland results in death. The *pineal gland,* if physiologically deficient, causes rapid sexual development. The *adrenals,* near the kidney, are another set of ductless glands the removal of which results in death. A deficiency in their action causes Addison's disease, usually fatal, and involving emaciation, characteristic change of skin color, and enfeebled heart action. Too much adrenal secretion raises the blood pressure, releases sugar into the blood, tones up the system, and excites the sympathetic nervous system. Some physiologists have suggested that nearly all the emotional changes of man will be better understood when an adequate knowledge of the functioning of the adrenals is reached. As are most of the other ductless glands, they are connected with sexual functioning, being enlarged during pregnancy. Insufficiency of the product of the *thyroid* glands, in the neck, checks the growth of the body, retards mental development, and results in

cretinism if the patient is very young. Feeding of thyroid material is resorted to in such cases. An excess of the secretion of this gland occasions excessive metabolism, excitement of the nervous system, anxiety and restlessness. These glands also are related to the functioning of the sexual glands. The *parathyroid glands* are another group essential to life. The degeneration of these in the young keeps down skeletal growth; the treatment consists of injections of calcium. Loss of weight follows their removal, together with muscular spasms similar to those produced by tetanus. The internal secretions, from the interstitial cells, of the *sex glands* control the sex traits. The removal of these glands causes the two sexes to approximate each other both physically and mentally. Some investigators have gone so far as to link the activity of the other glands with the functioning of these cells and to regard old age as a result of their diminished activity. Efforts have been made to accomplish rejuvenation through treatment of these glands and a field of future possible inquiry is at least indicated. Steinach, working in Vienna, was able to prolong the life of rats about forty per cent, but, so far as the human species is concerned, the evidence at present seems to indicate that a temporary stimulation, due to the protein material discharged into the blood stream, is the only result.

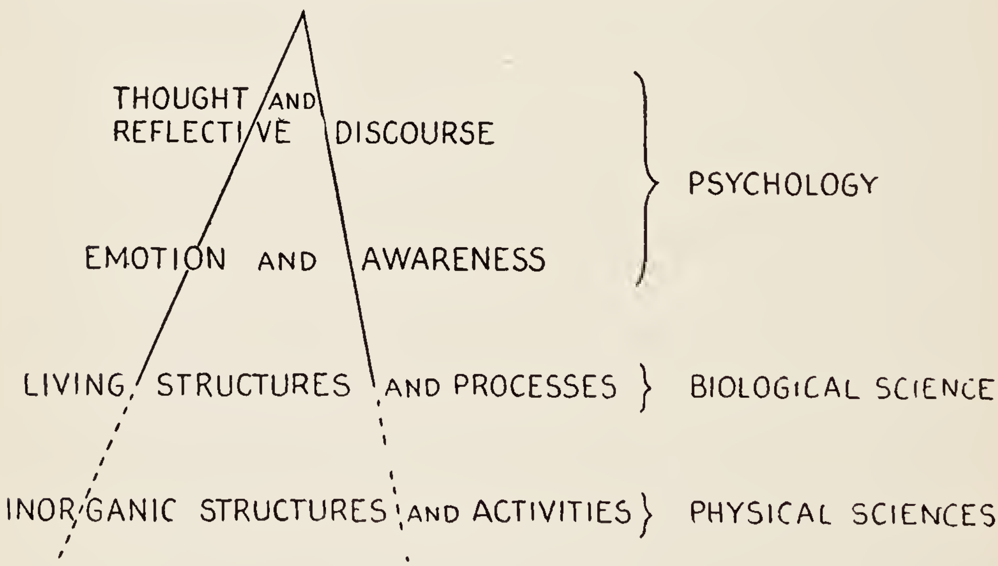

Fig. 11. Kinds of Activity

At the beginning of this chapter it was indicated that biology was differentiated from physics and chemistry by what was *done,* by the functions called life. There is no distinction more fundamental than the one here indicated. An ascending scale of activity can be traced, as indicated in the accompanying diagram, from the inorganic activities of the physical and chemical world, attractions and repulsions, osmosis, and the like,

through the instinctive serial orders of behavior in plants and animals, the superior adjustments made possible by the sense organs of developing animal life, up to the conscious awareness of man which culminates in reflective discourse. The discrete qualities distinguishable in this scale of activities are the basic distinctions in the subject-matter of the sciences. The next chapter has to do with the material indicated by the upper part of our diagram.

P. W. W.

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CHAPTER V

PSYCHOLOGY

1. Introductory

The science of psychology, since 1890, has developed more rapidly than any other general field of knowledge. Although every philosopher of importance since Plato and Aristotle has had a theory of the mind, it remained for psychological thinkers of the last fifty years to develop the science as an autonomous area of investigation. The renaissance of biology was followed by a renaissance of psychology. This latter science is still enjoying a " place in the sun," and boasts of a literature which is rapidly becoming encyclopaedic in volume.

The beginner in psychology faces many difficulties. While the student of biology may organize his knowledge around such well-accepted notions as evolution and the cell theory, in psychology there seem to be no such central doctrines to which he may cling. That is, there are none to which all psychologists will agree. The materials of the science present themselves, therefore, in an alluring disorder, with diverse schools investigating various data, and interpreting commonly accepted data in differing ways. There is not even unanimity of opinion as regards the definition of the science itself. To an older and more experienced mind these conflicts in the field appear as evidence of the luxuriously healthy growth of a rapidly developing field. To the novice, however, the divergent theories, couched as they are in strange technical terms, may seem but " confusion worse confounded." It is the aim of this chapter to indicate briefly for the beginner, (1) the nature of the science of psychology, (2) its field or fields of operation, (3) some of the schools at work on the various materials, (4) their methods and some of the results, and finally (5) certain fundamental notions, more or less agreed upon, together with some of their implications.

2. Definition and Division of the Field

What, then, is psychology? Aristotle at the beginning of his *De Anima*[1] says, " Our aim is to discover and ascertain the nature and essence of soul." Psychology was, for him, the science of " soul," whatever that might be.

[1] Edit. Bekkeri, 402a.

James called psychology the " Science of Mental Life, both of its phenomena and of their conditions."[2] Ladd defined it as " the science which describes and explains the phenomena of consciousness, as such."[3] A contemporary writer, Watson, states that " Psychology is that division of natural science which takes human activity and conduct as its subject-matter."[4] This definition makes psychology a sort of glorified physiology. Woodworth defines it as " the science of the conscious and near-conscious activities of living individuals."[5] So the definitions run. All of them emphasize as the subject-matter of the science either consciousness, *i.e.*, awareness, or a certain aspect of organic activity, conduct, or behavior. If another definition may be added to the already large assortment, we might venture the assertion that *psychology is the systematic attempt to predict and control conscious and near-conscious activities.*

It is a large field. On one side it shades off into physiology, the study of the more obvious vital functions, such as reproduction and digestion, of man and other animals. On the other it merges into a consideration of social relations and the activities, habitual and otherwise, which are the core materials of sociological investigation. It is well to recognize, however, that the so-called scientific " fields " are often differing methods of approach to common material rather than descriptions of radically different subject-matter. For example, the chemistry and physiology of reproduction as a living function are studied by the biologist. The activities of sex, as original activities and motives in human nature, their development and modifications, their related activities both native and acquired, are studied by the psychologist. The same matrix of subject-matter, already observed by the biologist and psychologist, may be described by the sociologist as it is found organized in what he calls the " institution " of the family. Again, nutrition is studied by biology as an indispensable living function; hunger as a motive, its attendant motives, activities and consequences are described by psychology. The social scientist, this time called an economist, also speaks of " demand " for edible articles produced by agriculturalists, and of a food " supply." The division of scientific fields is a purely practical matter of securing preëminently useful methods of approach to subject-matters open to investigation. Roughly, as any classification of the sciences indicates, they follow the divisions of the characteristics of the subject-matters themselves, in spite of great overlapping.

Psychology has justified its position as one of the major sciences; and

[2] James, William, *Principles of Psychology,* New York, Henry Holt, 1890, Vol. I, p. 1.

[3] Ladd, George T., *Psychology,* New York, Charles Scribner's Sons, 1894, p. 1.

[4] Watson, J. B., *Psychology,* Lippincott, 1919, p. 1.

[5] Woodworth, R. S., *Psychology,* New York, Henry Holt, 1921, p. 17.

it has come to stay. As a study of the functions of human nature which are not present, or discovered, in other animals, on one hand, or necessarily embodied in overt institutions, on the other, it can claim a large field of exclusive material which it shares with neither biology nor sociology. Its methods are, furthermore, extremely useful when applied to the vast bulk of material which it shares with other investigators.

A rather formal but useful way of indicating the divisions of the material of psychological study is obtained by four pairs of contrasts, as follows:

adult .... child
human .... animal
normal .... abnormal
individual .... social

Any combination of these terms, taking one from each pair, provides a field of study. Thus adult — human — normal — social psychology, and adult — human — abnormal — individual psychology are obviously the study, respectively, of (1) normal or average human adult groups and of (2) individual differences among abnormal adults. The divisions of the field are not so significant, however, as are the viewpoints and methods of the various investigators.

3. Some Psychological Viewpoints

The viewpoints in the field of psychology may be classified under four main headings. By this it is not meant that only four points of view are present, but simply that any psychologist will fall, for the most part, into one classification or another.[6] The divisions are as follows: (*a*) structural psychology (now called " existential " to distinguish it from *Gestalt* psychology), (*b*) functional psychology, (*c*) behavioristic psychology, and (*d*) dynamic psychology. As we shall see, these differences not only involve the use of unlike methods, but they also imply varying fundamental notions as regards the purpose of the science and the nature of " mind," " consciousness," or " soul."

(*a*) The *structural,* or existential, point of view[7] emphasizes " conscious states " as fundamental. By this is meant discriminated items of which the particular person may be aware at any time, such as sensations

[6] *Cf. Psychologies of 1925,* Clark University, 1926, in which the following classification is suggested: (1) Behaviorism, (2) Dynamic Psychology, (3) *Gestalt,* (4) Purposive Groups, (5) Reaction Psychology, and (6) Psychologies called " structural."

[7] The works of E. B. Titchener are written from the structural point of view. The viewpoint is also called " introspective " psychology, from the method it uses.

or feelings. One may have a *sensation* of blue, or a *feeling* of anger, and so on. Out of these states of consciousness the mind is supposedly compounded. The aim of psychology, on this basis, is a description of conscious life involving an analysis, as complete as possible, of all items which can be classed as conscious states. The dominant method is introspection, *i.e.,* the individual consults his own inner consciousness as regards the qualities of which he is and has been aware, and analyzes under controlled conditions the varying qualities which appear. The result may be called a morphology of consciousness.

This approach to psychological work developed out of the so-called association schools of psychology which preceded the recent rapid growth of the science and, therefore, has the prestige of being early in the field. Furthermore, the introspective method has considerable value. Unless it is used, how would we know, for instance, that action becomes unconscious as it becomes habitual? Again, introspective analysis of thinking brings out the fact that it frequently is internal speech, a species of silent argument. At the risk of being a bit paradoxical we may say, however, that the method of structuralism is of more use than are its fundamental notions. The method of introspection has its uses, but the notion that consciousness, or mind, can be compounded out of " states " is full of obscurities. Although structural psychologists have analyzed conscious " states " very admirably, even as the chemist has examined his elements, at no time has a formula of any value been produced. To follow the analogy, chemical analysis yields a formula for chemical compounds in terms of which prediction and control are possible. Structural psychology has no such formulas to offer. To compound " consciousness " or " mind " out of " states," sensations and feelings, seems about as useful as describing motion in terms of an infinite number of locations or states of rest. Motion is not rest, and " consciousness " is not a " state " ; at all events, if it be called a " state," it cannot be regarded as a state *of itself.* Furthermore, the structural viewpoint neglects the study of reflexes, habits, and all extra-conscious material. It refuses, so to speak, to go behind the scenes of the drama of consciousness to see what can be found there.

The fundamental difficulty, however, is the ambiguity in the notion of " consciousness." The term has at least four distinct meanings. First, it may mean the *object* of which one is conscious, *e.g.,* the blueness of a vase. Second, it may mean the *act* of being aware, *i.e.,* the process of becoming or being conscious. Third, it may mean a *conscious stuff* which arises when attention is paid to some subject-matter, *e.g.,* the sensation of blue, thought of as something other than, and distinct from, the blueness of the observed vase. Fourth, it may mean the *" mind," or " self,"* which is conscious, thought of as a thing which acts. Is " consciousness " the object of which

one is conscious (*e.g.*, this vase); is it the process of becoming aware of the vase; is it a something which comes between one and the vase when attention is paid to the latter; or is it a "mind," or "self," which has the awareness and does the thinking?

(*b*) The *functional* point of view [8] arose as an effort to supplement the apparent inadequacies of structuralism. Conscious *processes* are its subject-matter. "Let the structuralists talk about the content of consciousness all they will," said the functionalists, "we will study its physiology — not percepts but *perceiving,* not concepts but *conceiving* — and we will see what difference it makes that there should be such processes." These functionalists made great advances. They had the insight to see that activity was somehow the core of the matter. And yet, activity of what? Was a mental function an activity of the "mind," was it the activity of some other "mental" stuff — sensations, or feelings — or was it the activity of the nerves, or physical body of man? The ambiguity of the term "function" became as apparent as that of consciousness.

(*c*) The third point of view rules "consciousness" out of consideration. *Behaviorism* [9] takes the position that conduct is the proper subject-matter for psychologists, that nothing else is really open to investigation. "You can see what a man does and study it, and the same is true of other animals,"[10] says the behaviorist, "but what they think — well — that is irrelevant anyway. Study what they do, and when and how one doing follows another. Then we will have a science rather than a mythology in this field of psychology." Psychology becomes, on this basis, the science of behavior, a higher physiology. For by "behavior" the behaviorist does not, by any chance, mean function or activities of a "mind"; he means overt, visible movements of the body. Obviously, if such activities are the proper subject-matter of psychology, there is no important place for the introspective method. What you *think* you did is not important when the scientist has already observed what you actually did. Therefore behaviorism uses the same methods employed by biological science. In antithesis to structuralism, the behaviorist says that the individual does not develop a "consciousness" or "mind"; the individual's behavior develops. His conduct merely becomes more complex and subtle. Thus, in the notion of a developing *behavior,* the behaviorist has a substitute for "consciousness" in the traditional sense.

[8] Angell's *Psychology* is an illustration of this. Angell was under the influence of Dewey. The functionalists have for the most part outgrown their general position in such a way as to make it only historically interesting. This is rapidly becoming true of structuralism as well, excepting as *Gestalt* may be so classified.

[9] Watson's *Behaviorism* is an illustration of this viewpoint.

[10] Behaviorism originated historically in animal psychology.

This viewpoint, together with the following one, fascinates the social scientist who is looking to psychology for information which will help him deal with institutions. Behavior, visible, tangible, concrete, is the stuff of which society is made. "Consciousness," in contrast, is the "stuff that dreams are made of." And it is obvious enough that jurisprudence, to take one social field alone, would be greatly helped by a genuinely scientific approach to human behavior, for to control practically that behavior is exactly what law aims to do. As regards the defects of the behavioristic position, it can be pointed out that the greatest weakness lies in the fact that it neglects what goes on within the organism — between overt "stimulus" and overt "response." As we shall see below in the analysis of the "reflex arc," the mechanical conceptions of extreme behaviorists are too unyielding to deal adequately with certain types of activity. To deal merely with *overt* actions is to miss a large part of the proper subject-matter of psychology. That subject-matter may be hard to discover, but to deny that it exists is like denying the existence of the other side of the moon because we cannot see it.

(*d*) The fourth viewpoint in psychological science is called *dynamic* [11] psychology. Impulses, motives, tendencies, drives, are the subject-matter emphasized by this group of investigators. "Dynamic" comes from the Greek word meaning "potentiality"; and the dynamic viewpoint is interested in the power which drives the machinery of conduct. If we picture our conscious life grossly as a machine, the structuralist is interested in the anatomy of it, the behaviorist in what it does, and the dynamic psychologist in the motive power which makes the wheels go around. "It is not enough to know *that* we do things as we do," says the dynamic psychologist; "it is not enough to say that this overt behavior is followed by that overt behavior; but we must catalog the springs to action which lie back of conduct and which emerge, with various modifications, into overt action. We must know the *what*, of course, but also the *why*." And so he attempts a classification of the various impulses of man's original nature, and an analysis of these native traits as they issue in, and are modified by, overt expression. This viewpoint is both more recent than structuralism and more generous than behaviorism. It does not discard introspection as altogether useless, nor does it deny that prediction and control of behavior are the aim of the science of psychology, but it holds that a mere inspection of "consciousness" gets nowhere, and that an observed correlation of overt activities in many instances merely states

[11] Woodworth's *Psychology* and *Dynamic Psychology* illustrate this point of view. The Freudians are another illustration; their notion of the "sub-conscious mind" as seething with suppressed desires and motives, which influence and condition conscious life, is a peculiar form of dynamic psychology.

the problem. "An adequate psychology," says the dynamic psychologist, "must get behind the scenery of both conscious states and overt behavior." This fourth viewpoint is also of interest to the social scientist. Are not the "springs of action" the very things which lie back of human life and which condition both its institutions and its individual variations? Would not a knowledge of these and of their development make possible an improved educational system and better social control? For the present let us be content with the observation that dynamic psychology has important implications for social science, and pass on to a brief review of the general methods of psychology.

4. General Methods of Psychology

In psychology, as in the other sciences, the general characteristics of scientific method are illustrated. There is always a subject-matter which is observed, there are inductive inferences or hypotheses, and deductive inferences from these by way of specific predictions. There is verification by further observation, by predictions and controls which are instituted in terms of the hypotheses used. Observation by *controlled experimenting* is prominent in the science, whether in the introspective procedure of the structuralist or in the observations of behavior by the behaviorist. In both procedures the subject-matter, a "conscious state" or a "response," is produced under definite conditions and analyzed by various manipulations and substitutions. The *genetic method* is very different; it tries to get at the facts by a historical tracing of the developments of the individual or individuals under observation, and is obviously supplementary to direct experimentation. The *pathological, or clinical, method* is simply a name given to the diagnostic analysis of abnormal cases; it is so named because of its similarity to medical observation, or diagnosis, of diseases. The so-called *comparative method* is a way of describing observed likenesses and differences, whether among specific individuals, groups of individuals of the same class, or differing species of individuals. Likenesses become norms; when statistically expressed they are averages. Differences become variations from the norms. And so the process of detailed observation goes on. Tests of various kinds are devised, thereby introducing a partial control and giving a semi-experimental character to the analysis. The results of various tests, expressed statistically, make possible certain limited predictions and controls. Our knowledge is admittedly inadequate, but it is much better than complete ignorance.

As a further introduction to the field it will be useful to give a brief description of certain notions which psychologists have worked out as their science has developed. Some of the notions which we will describe are im-

portant because they are fundamental, and others because they are in very general usage. In the compass of a single chapter it is impossible to present more than a very few of the interesting theories of this science.

5. The Concept of Original Nature

No notion is more important for psychology than that of *the original nature of man.*[12] In early modern days, it was thought that man's nature was primarily *rational, i.e.,* that reasoning was the fundamental human attribute. The doctrine received great emphasis from time to time, as in the period of the French Revolution. All man's actions were interpreted in terms of "judgment." Since man was rational, logic must be the avenue of approach to his nature. Today we know better. The notion of original nature as used in contemporary psychology means the *matrix of unlearned activities out of which man's mature character develops.* It is through a knowledge of these activities that we must approach logic and not *vice versa.* The original stuff of humanity is thought of as a series of dynamic unfolding processes which are progressively conditioned by the environment which they encounter. Man is fundamentally a *living animal* rather than a *logical process.* When we attempt to say what this matrix of activity involves, however, intricate difficulties appear. Obviously not all the characters with which a man is born are native — he may be crippled or diseased by virtue of his pre-natal environment, and have consequently a stock of "congenital" characteristics. His native activities, however, are those which are not acquired, either before or after birth. They may appear at birth, as do breathing, jumping at a noise, grasping, sucking, and swallowing; or they may be relatively late in unfolding, as sex activities and scientific and artistic capacities.

The original activities have been popularly classified as (1) *reflexes, e.g.,* the pupillary reaction, (2) *instincts,* such as food and sex, and (3) *native capacities.* Reflexes are very specialized responses, specific and involuntary. The instincts are serial orders of acts, modifiable and susceptible of indefinite suspension. To contrast the two, no man can alter the reflex action of his pupil by conscious habituation or control, but "hunger strikes" are entirely possible, even, as with McSwiney, the Lord Mayor of Cork, to the point of death. Instincts are more complex than reflexes and are, so to speak, open at both ends. What sets off the series of activities, and what terminates it, is not so fixed as in the case of reflexes. We must eat to live, for example, but *under what conditions* and *what* and *how* we eat is not determined. The third phase of original nature, native capacities, in-

12 *Cf.* Thorndike, E. L., *Educational Psychology,* Vol. I.

volves still more complex and controllable factors. These are really vague potentialities. In contrast to instincts they have no specialized organs through which the activity converges; nor are the various patterns which behavior assumes definitely set. Many of the activities classified under this head are to be thought of as grafted upon organs originally of use, and perhaps of biological survival value, in other ways. Thus musical ability may mean the capacity to develop great manual dexterity at the piano. The human hand, however, possesses its present form because of the arboreal life of some of our sub-human ancestors, and it had this form long before musical instruments were invented. Looked at in this way, the capacities of human nature are theoretically indefinite, although in any specific situation they are very definitely and precisely limited. Indeed, the negative aspect of human nature is as important as the positive. A correct notion of the original stuff of humanity will teach us not to expect or to attempt the impossible.

The word *impulse* is extremely useful as applied to all man's original tendencies because of the fact that it suggests the unorganized pulse of his organic activity. Man seemingly has more original impulses than any other animal; and they are more loosely knitted together than in other animals. These two facts taken together account for man's remarkable *plasticity*. He can develop a rich and varied life, a profusion of differentiated activities. Indeed, he is so rich in this stock of activities that they get in each other's way and thereby leave room for conscious redirection. A being with only *one* native impulse could never be intelligent. It could only act, and act in one way. But an animal with a wide variety of possible responses in any situation has at least the chance of working out a technique of selection among those responses. We can see that intelligence, insofar as it is thought of as native at all, is a native capacity — a capacity which is more or less a direct function of the profusion and richness of our other activities.

6. A Classification of Human Activities [13]

A more scientific classification of our native impulses, in contrast with the gross distinctions of reflex, instinct, and native capacity, is achieved by regarding them in cross-section, so to speak, rather than longitudinally. That is, we ask the question, what various aspects may be displayed by all original impulses? Are there general characters which they all have in common, and which we can distinguish by analysis? When a classification of our fundamental activities is attempted in these terms, a four-dimensional theory emerges, as follows:

[13] The author is indebted here to Professor John Dewey.

TABLE IV. CLASSIFICATION OF HUMAN ACTIVITIES

	Neutral state
1. In terms of *direct relation to the environment* our responses are *seeking* or *shunning*	*attachment*
2. In terms of *progressive success* or *failure* they possess *expansion* or *depression*	*evenness*
3. In terms of *intensity* they have *excitement* or *quiescence*	*indifference*
4. In terms of *intra-organic adjustment* — (*i.e.* among themselves) they are *agreeable* or *disagreeable*	*uncertain*

A child *seeks* its mother's breast; failing in its search, it is *depressed.* Its searching may increase in intensity; it becomes *excited,* or even frantic, in its hunger. Success is *agreeable* and *expansive;* failure, and continued hunger, is *disagreeable.* To change the illustration, men fighting against overwhelming odds might *seek* open combat as more *agreeable* than inaction; and although *depressed* by the presence of certain defeat, fight their last fight with a ferocious and *excited* intensity.

It is not always easy to detect the differences between the native and acquired aspects of various activities. The activities appearing normally at birth are native, as we have indicated. But when an activity appears late in the unfolding of the individual, it is more difficult to distinguish the native factors. If, by experimental control, the possibility of learning is eliminated, then the maturing activity will be native. Spalding's famous experiments on birds in 1873, one of the earliest bits of work in animal psychology, established the fact that the flying of birds is native. He took newly hatched birds from the nests and cooped them up individually in such a way that they could not see other birds fly, or stretch their own wings. When they reached adult age, he released them and the birds flew away. The muscular coördinations necessary for flying had matured by nature. Scott, by similar processes of experimental control, ascertained that the specific songs of birds are acquired. He kept young orioles away from older birds, and as they matured they developed a new song, one not typical of the oriole. Younger birds brought up with these birds which had invented the new music adopted it.[14] To make some kind of sounds with his vocal organs seems to be native to man also; but, as with birds, learn-

[14] *Cf.* Ch. I for a brief discussion of the acquired activities of man.

ing and the conditioning process determine what sounds he makes. Any mature character of man is an intricate combination of nature and nurture, of original impulse, plus the development and modifications imposed upon it by its environment.

This naturally leads to the question of *how* an activity is altered by the environment. How are original activities so changed that the mature character of the animal can be vastly different from its bare original nature? Formerly psychology explained learning and habit-formation by the *association of ideas*. Today this process is described by the theory of the *conditioned reflex*.

7. The Concept of The Conditioned Reflex

A reflex, as we have seen, is a specific response, very specialized and occurring spontaneously upon a given stimulus or change in the environment. *A conditioned reflex is an altered reflex, one that has been changed*

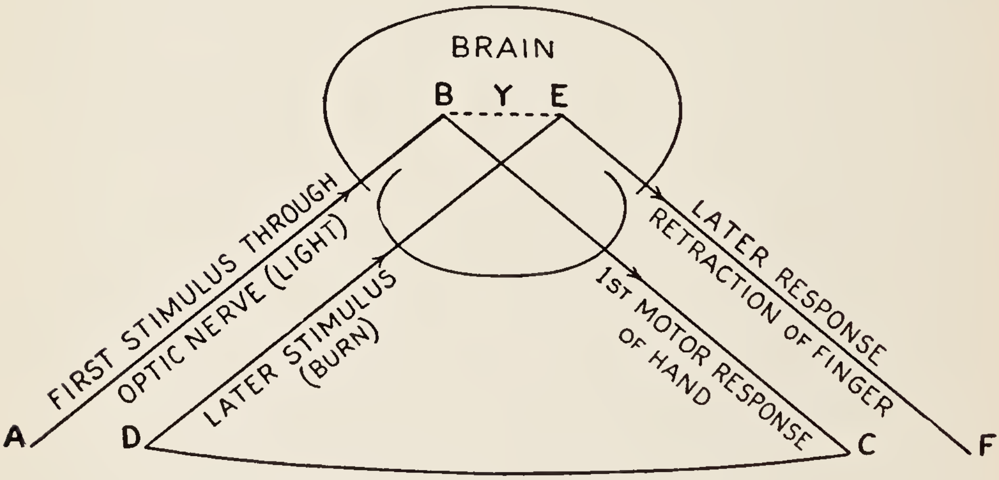

Fig. 12. The Physiology of the Conditioned Reflex

in character by exercise. For example, saliva flows in a dog's mouth at the sight of meat. This is a native response. If a bell is rung repeatedly at the same time that the meat is displayed, the dog will finally come to respond to the mere ring of the bell, without the meat, by a flow of saliva. A small infant confronted with a lighted candle spontaneously reaches for it by way of response; this response is terminated by the additional stimulus of a burned finger, followed by retraction of the hand. The reflex has been " conditioned " and the next lighted candle is not grasped with the fingers, but is avoided. The physiology of this process may be illustrated by the diagram herewith.

The activity passing through the circuit A B C D E F receives a conditioning by virtue of which a future candle light (*i.e.,* repetition of stimulus AB) is followed by retraction of the hand (EF) *without the reaching and burning intervening.* This is explained by the insertion of the organic factor Y in the brain, which eliminates the response resulting in the burn. " A burned dog shuns the fire," as the old adage goes, and so does a burned baby! From the very first minutes of life our activities receive a progressive conditioning in terms of the responses made.

Obviously the notion of the conditioned reflex is fundamental; however, the contrast between *stimulus* and *response* is presupposed by it. Psychologists use the notion of stimulus-response as a means of describing all activities of the organism. Thus an original impulse is a tendency to respond in one way rather than another when confronted by certain stimuli. The term *tendency* indicates a drift of activity, a direction of movement. Our activities are loaded, so to speak, in one way rather than another — they are naturally preferential. This preferential character of human activity is called *original impulse* when it appears previous to, or apart from, any environmental influence. Original activities are the preferences of the species. The *conditioned reflex* notion simply states the way in which the preferential character of activity is progressively altered. When put in this way, it is apparent that the stimulus does not *cause* the response. No amount of stimulation will cause a dead man to respond! If we think of the stimulus as occasioning the response in the way in which the movement of one cog-wheel causes the movement of another, we falsify the situation. The activity is *already there* and *already preferential;* if it is not already there, you never get it. It is much fairer to say, therefore, that successive stimuli progressively alter the preferential character of the existing aptitudes, and to recognize that the particular response is not *caused* by the stimulus, in any adequate sense of the word, but is the result of *particular stimulus plus existing tendencies.* A particular stimulus occasions widely varying responses on the part of different individuals. The aptitudes existing in the responding individuals, in a given situation, do not make a little difference, therefore but *all* the difference.

8. The Psychology of Intelligence

Admittedly there is no straight road from the physiology of the conditioned reflex to the higher conscious processes. There may seem to be such a way to those who believe, with Herbert Spencer, that intelligence results from the compounding of reflexes, or to those who hold that intellect is a specific impulse original in man's nature which matures along with his other tendencies. However, activity can go on being conditioned indefi-

nitely without occasioning any rise of consciousness. It is difficult to see how the mere compounding of reflexes would result in conscious reflective behavior. Nor does the analysis of original nature reveal any specific activity of a cognitive sort which could, of itself, mature into the kind of activity which we call intelligent. Habitual activity is, moreover, notoriously unconscious.

In attempting to answer the question of how consciousness arises we are confronted with several alternative theories. Perhaps no entirely adequate explanation is available. The theory which gives the best predictions and yields the most adequate controls is the one which we should accept. As has been implied above, some other element, over and above the conditioned reflexes, must be involved. Otherwise activity would continue on its adaptive but unconscious and unreflective way. The factor which seems to occasion consciousness and makes possible reflection is a *conflict* [15] among the various tendencies within the organism. This is another way of saying that intelligence is problem-solving in character. When alternative drives or impulses impede each other and a prolonged state of strain is induced, the environment is thrown into relief in a peculiar way. Conscious reflection is, therefore, a kind of respite activity. It comes in the pause of overt action. The organic activity is shunted one way and then another within the organism as the process of reorganization takes place. In other words, reflective processes are not specific impulses among other impulses. They are processes of reorganization, of summation. Intelligence appears when other activities have failed to carry on, when they are blocked and helpless. The awareness arises, moreover, at the point and time of difficulty. The blocking of overt responses produces an intra-organic shattering of activity which we call emotional perturbation. In cross-section, so to speak, consciousness is emotion. This may seem a strange notion, but it may become clear when we add that the activity which in cross-section is emotion may, longitudinally or temporally considered, be intelligence. The shocks, stresses, and strains of the emotional disturbance, when they are used as signs of other activities to be subsequently engaged in, assume a cognitive *rôle*. They mean things other than themselves.

This taking of one thing as meaning another is the differentia of intelligence. A present activity carries the import of future responses and of events which, in the nature of the case, cannot be present. Furthermore, because the present activity can carry the feel of future response with it, we come to respond *as if* the future activity or event were present. After being burned the child retracts his hand at the sight of the candle. If

[15] *Cf.* Dewey, John, *Human Nature and Conduct,* pp. 190 f. The author wishes to acknowledge again his debt to Professor Dewey.

consciousness is involved at all, and it need not be on this level, we would say that the light *meant* a possible burn — a burn which *did not take place* for the very reason that the response engaged in (seeing the light) carried with it the feel of the future activity (the reaching plus the burn). In other words, when present responses carry with them the import of future activities, we tend to alter conduct in response to those futures; the anticipated activities enter into present conduct *as part of the stimulus* to which response is made. In a typical case of deliberation, when the problem is being analyzed, the individual " feels out " one possibility after another as the focus of awareness shifts from one activity to another. Finally some activity assumes a pivotal position and a reorganization is effected in terms of this — a reorganization which continues until another block is faced and another disintegration imposed. Then, of course, consciousness recurs and another problematic situation develops.

Strange as it may seem, it is the past conditioning which gives us the feel of future events. The retained effects of our past responses, called memory, are translated into the future. In deliberation we consult memory, *i.e.,* our activity shifts off into those brain centers where the effects of past acts are retained — we " stop and think," for instance, in response to the stimulus of being lost. Eye, ear, and memory are consulted one after another in the effort to reorganize our action. Finally the stimulus is hit upon which enables us to recover our sense of direction — perhaps through a memory of a map of the country, the sight of a signpost or the position of the sun, or the audible word of some passer-by. Obviously, apart from the conditioning of our activities, we would never learn anything. We would, consequently, be nonplussed by every problem, because of the absolute novelty of each situation. As it is, we can systematically anticipate the future, and by using words and language as artificial signs, we have worked out an elaborate technique of prediction and control.

It has been suggested above that the taking of one activity or thing as the sign of another is the differentia of intelligent action. This is another way of saying that intelligent action is action in the light of consequences; intelligence is the anticipation of consequences. When our activity is blocked and disintegrated, we rehearse, in imagination, the consequences of the modes of action which present themselves as possibilities. Our activity does not stop, but turns from overt behavior into intra-organic channels. Each conflicting habit and drive which enters into the situation projects itself upon the screen of imagination. The most important advantage of this is obvious enough. The activity is " tried on " in such a way that its resultant effects become apparent, and irretrievable consequences can be avoided. Overt action would produce definite irrevocable results. Success or failure would result at once. By rehearsing the conse-

quences of alternative courses of action ahead of time, the undesirable results can be shunned and the desirable ones sought.

The character and *rôle* of intelligent activity is a fascinating subject, well worth profound study by everyone. We pass on to a brief review of several related notions in psychological science. The first of these is very closely related to intelligence, for it has to do with the evolution of language.

9. Language

Thought and language developed hand in hand. As man became intelligent and came to use things as signs of each other, he hit upon artificial signs; the activities and attitudes which stirred within him were indicated and vocalized as variations upon the native grunts and sputterings which he spontaneously made, or they were pictorially displayed in written symbols for other eyes to follow and take heed. The first written symbols were pictographic forms following visual impressions exclusively. The next step in the development of language was the gradual reduction of pictographic forms to their lowest possible terms — the development, that is, of symbols which carried over only a small part of the original image. The figure below gives, in brief, the evolution of the letter *M* from its pictographic original: [16]

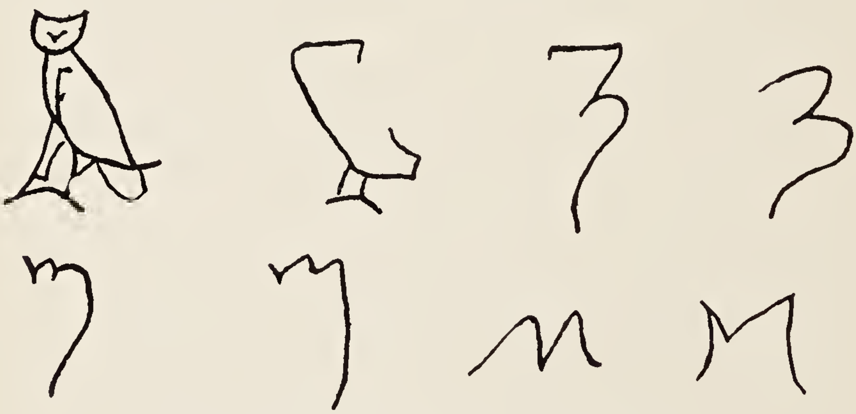

Fig. 13. The Evolution of the Letter M

The upper forms are Egyptian. The first is the usual hieroglyphic picture of the owl, or, in the Egyptian language, mulak. The others are found in the writings of the Egyptian priests. On the left of the lower series is an ancient Semitic form. Then comes an ancient Greek form, and two later Greek forms. A third, and most important, step was taken when these reduced pictographs were used not as visual maps of the natural objects to

[16] *Cf.* Taylor, I., *The Alphabet,* London, Kegan Paul, Trench & Co., 1883, pp. 9–10, cited by Judd, C. H., *Psychology,* Boston, 1917, pp. 219 f.

which they referred, but as indicating *sounds* of spoken language. The Phoenicians are generally credited with the invention of this usage of written symbols. And a very important and revolutionary invention it was, indeed! The variations of pitch and stress with our vocal organs are potentially infinite in number. Combinations of written symbols can be made to convey these by affixing a certain sound to a certain symbol. Written language thus became parasitic upon spoken language, so to speak, and both types of artificial signs throve by the arrangement. Our inmost attitudes and reflective activities not only can be made systematically available externally, by means of vocal signs, for others to use, but also they can be visually recorded, in all their intricacy, upon pages which all posterity may read.

10. Some Other Psychological Notions

From what has gone before we can see that activities are the subject-matter studied by psychology. Activity is fundamental to each notion of the science, whether original nature, emotion, sensation, intelligence, prejudice, habit, or some other item is being discussed. *Character,* for example, is simply the individual's stock of predispositions to respond in certain ways to certain stimuli. *Prejudice* is likewise a certain kind of predisposition — a tendency. Abnormal psychologists use the notion of the *complex* to represent the kind of distortions which they meet in their patients. A complex is an unconscious push which, upon repression by some other tendency, throws a distorted picture upon the screen of the individual's consciousness. Frequently items of conscious life totally unrelated logically to the impulses involved are subjected to distortions, as in Jung's case of the man who hated the bells of a certain church because of his dislike for the clergyman, a rival of his in amateur poetry! The conflict present in such a case is not the kind which issues in an intelligent conscious solution of a problem, but involves a pressure of some activity which is blocked from conscious consideration because of other tendencies of the individual. The man in the illustration just mentioned [17] would not admit to himself that he disliked so harmless a gentleman as the good clergyman. Therefore he hated the bells, although they were good bells, excelling in all those points which constitute the goodness and beauty of bells. Had he known the cause of his dislike, he would have had to admit its unreasoning character. The term *complex* is popular among the Freudian school, and is used by them to refer to drives or motives which may be predominantly either native or habitual.

Rationalization is another term which occurs in this connection. It does not refer to rational conduct, *i.e.*, intelligent behavior, but is a technical

[17] *Cf.* Hart, Bernard, *The Psychology of Insanity,* pp. 98 f.

term indicating the process of unconscious apologetic which we frequently carry on. We " rationalize " when we attribute to our acts more worthy motives than really exist. We are frequently like the fox in the fable who rationalized his not trying for the grapes on the ground that they were sour! If, for example, we are insulted and yet afraid to be agressive in return, we may say that we are preserving our " dignity." Our fear has been thereby rationalized, and we are spared the thought that we have been cowards! There are people whose characters are such that they act predominantly from prejudice or habit, and whose intelligence is degraded into a perpetual camouflage artist for their brutal and unreflective behavior. Instead of pausing, reflecting upon the consequences of alternative courses, and then acting, they act first and afterwards invent high-sounding " reasons " for their conduct.

11. Applied Psychology

Of the application of psychological knowledge we shall have more to say in subsequent chapters, but certain items may be of use here by way of suggesting the scope of the applications which can be made. Law, medicine, and religion, all have their psychological sides. Witnesses and juries, patients and penitents, are human beings with their original tendencies, their habits, and their prejudices. In industry, also, the problem of motivation is involved, and the handling of personnel is so important in this field that it is done by specialized officers within the various organizations. In advertising, and selling in general, a knowledge of psychology is important. Apart from its legitimate use, a salesman who is clever can frequently sell men articles which they neither want nor need, and without which they would be positively better off! [18]

In a great many fields in which the use of psychology is of minor importance it is called the *psychological method.* A knowledge of psychology is fundamental to the successful handling of other people, whether individually or collectively. A public speaker, for example, who knows human motives would never waste his time explaining the value of the literary criticism of the Bible to an audience of fundamentalists. Nor would he address the Knights of Columbus on the benefits arising from the Protestant Reformation! Even the simple process of telling a humorous story has its psychological side. A funny story must be so designed that its point releases the latent energy of some motive or drive of the hearer. If those who listen do not have the particular prejudice or drive which the

[18] *Cf.* Chase, Stuart, and Schlink, F. J., *Your Money's Worth, a Study in the Waste of the Consumer's Dollar,* New York, Macmillan, 1927. This book should be read by everyone as an antidote to contemporary advertising!

story presupposes, the yarn " falls flat." Holt tells [19] of an after-dinner story related by one unwitting gentleman, when the hostess of the occasion happened to be a Christian Scientist. The story was to the effect that the pet cat of a Christian Scientist family had very pitifully given birth to blind kittens. A Christian Science healer had been informed, and had given absent treatments for a period of ten days. Marvelous to relate, at the end of that time the kittens were restored to perfect sight! The joke was a " frost." It presupposed on the part of the audience a conviction which they did not possess. Clearly enough, any story will be humorous only to people of similar predispositions. The reason why the popular humor of the stage and platform is so banal is that it can be couched only in terms of the grossest and most universal drives. For example, we all enjoy to some extent the discomfiture of others (perhaps because of a rather universal feeling of jealousy and rivalry), and the more pompous and " high-hat " others are, the more fun we derive from their confusion. Some gentleman dressed like the " glass of fashion " who trips over his cane and rolls his silk topper into the gutter is unquestionably funny. But the story-teller and joker must be careful. If the pompous gentleman has hurt himself seriously, and lies on the pavement writhing in agony, our smile is immediately replaced by a profound sympathy and pity. The whole question of wit and humor concerns the nature of the predispositions involved and the way in which they are tripped or released.

In conclusion, one of the more important fields of applied psychology is that of educational theory. In the conscious moulding and developing of young life a knowledge of the materials involved is indispensable. These materials are primarily, of course, the activities of human nature. A sane psychology will tell us, in the first place, what we *cannot* do. " You can't make a whistle out of a pig's tail," as the old adage goes, nor can we expect idyllic perfection from such stuff as human nature; but our natures are good for some things and for those things we may be educated. How we are to be educated is for psychology to say. The correct principles of education ought to follow as simple deductions from psychological science. At present psychology helps education by suggesting new methods, by criticizing old methods, and by providing means of measurement. Precise measurements are important because, apart from them, the whole business of education is merely pious guess-work.

One of the recent developments along this line is the *intelligence test*. Since Binet published his individual test in 1905, various individual and group tests have been devised to test the general levels of students' abilities. The test may be arranged in levels of increasing difficulty, ranging up to " average adult " and " superior adult." The child is then put through the

19 Holt, E. B., *The Freudian Wish*, pp. 17 f.

tests, and an eight year old who scores points totalling VIII is 100%. If he scores VI, he is 75%, *i.e.*, he has a six-year-old "mind," although eight years in age. The percentage figure is called the "intelligent quotient" — the I.Q. In group tests the results are similar. A series of tests is set with a norm already established; the ratio of the individual's score to the norm then gives his I.Q. Children whose I.Q.'s are from 90 to 110 are considered normal. If the average intelligence of the whole population be regarded as 100, it is clear that an individual must be above 100 to enter college.[20] An I.Q. of 80 to 90 indicates dullness; 70 to 80 is doubtful. Morons lie between 50 and 70, imbeciles from 25 to 50, and idiots below 25. To give one illustration, a boy eighteen years old with a "mental age" of nine would have an I.Q. of 50, and be classed as a low-grade moron. Morons never run above eleven years in "mental age"; imbeciles, in terms of "mental age," are from 3 to 7, and idiots are below that.

It is well to remember, in using a mental test, that *performance* is registered by it. In this respect it is like any other test, and correlates positively with other tests, for example, with the average grade of students in the freshman year of college. *Performance* is not *native ability,* however; it is *native ability plus opportunity.* An average I.Q., scored by a child in an impoverished social environment, would mean unusual ability. The same performance, at the same age, by one with an unusually good social environment would indicate mental dullness. Generally speaking, however, intelligence tests are reliable enough to be of value in education.[21] Their present vogue is sufficient evidence of their utility. Any and every means of measurement invented by psychology is welcomed by educators. The more accurately the schools can measure what they achieve, the better they can know how to do it.

P. W. W.

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[20] Yoakum, Clarence S., and Yerkes, Robert M., *Army Mental Tests,* New York, Holt, 1920. Also, *National Academy of Sciences. Memoirs,* Vol. 15.

[21] Their coefficient of correlation is around +.60.

CHAPTER VI

HISTORY

1. Introductory

History is the interpretation of human records. It is constructed from the evidences of past human events. History does not deal with the past events themselves, even as biology does not study living trilobites. But the evidences of both trilobites and past human events are available for the biologist and the historian respectively. Consequently there can be both a paleontology and a history. Indeed, every science has its historical side. Whenever past subject-matter is handled and inferences made, from this or that fact of record, about some previous state of affairs, history is being made. " History " is not a name for the past in general, or for any particular career in time. It is always the history *of* something. Where the subject-matter of a science is present and open to analysis, as in large areas of physics, chemistry, and biology, the historical side of the subject is of secondary importance, though it still may be studied under the heading of " genetic method." Where thought can be experimental, it abandons the records of history, but where it cannot experiment, it must make such use as it can of the remains which are available. Thus, in astronomy and geology, we try to infer the previous condition of the solar system and the earth, not only from observations of other solar systems but also from the records of the rocks. History, however, is not the " natural history " of days gone by, when natural science was in its infancy. It is humanistic; it focusses its attention upon *man* and aims to present descriptively such significant evidence concerning important past human events as can be ascertained. As such, it provides the ground-work for all social science. It gives the account of the past careers of those human energies which psychology tries to study experimentally.

The importance of history is very great because of the undeveloped character of social science. While social science waits for a Moses to lead it out of its wilderness, history can at least be ascertaining as far as possible what men have done under certain conditions in the past. The enterprise is necessarily restricted; it is a poor substitute for an adequate knowledge of society. The fact is that history is not a science at all, in the strict sense of the word. History is a method, the " genetic method " of social science. The emphasis upon human history is a groping insistence upon

trying to understand ourselves. What do the records show that men have done in the past? Perhaps we shall do these things again, perhaps not. But at all events history can tell us something of what human flesh is capable and thereby enlarge our knowledge of each other. History is the attempt to interpret the past and to promote understanding.

2. The Materials and Subsciences of History

The records of human events are multiform; history, consequently, is pluralistic. By this is meant that history is composed of series upon series of differing data — a patchwork of records of indisputable value pieced together by less reliable ones and many happy guesses. Large numbers of ancient records have disappeared, and the bulk of modern material is too stupendous to be easily arranged. The aim of historical scientists — to reconstruct from authenticated materials a picture of past events, to provide a documented cultural memory, so to speak — is difficult of attainment.

The forms in which the materials of history are found may be classified under various headings. Some deliberate historical works were written even before Herodotus, who is called the "father of history." Genealogies, chronologies, annals, and biographies without number are available for study. Many so-called non-historical works, such as judicial writings and philosophical speculations, are nevertheless useful as culture-history material. Another class of materials is composed of public acts such as treaties, public addresses, inscriptions of historical import, together with laws, inventories, letters, and sermons, which throw light on public matters. Still a third class of materials — and the classifications can be indefinitely multiplied — is composed of monuments, triumphal arches, tombs, medals, and such non-historical objects as utensils, money, arms, and objects of art. These will serve to indicate the profusion of materials which human events, in passing, leave behind them to serve as the facts of history.

The auxiliary sciences of history, having to do with various classes of relevant materials, may be indicated as follows: [1] *paleography,* the science of ancient manuscripts; *diplomacy,* the study of records of public policy; *epigraphy,* the science of inscriptions; *sphragistics,* that of engraved seals; *numismatics,* the science of coins; *archeology,* the science of the remains of previous cultures; and *chronology,* a separate subscience dealing with calendars. To these must be added both *geography* and *ethnography,* natural sciences which are indispensable to the study of human records. It is scarcely necessary to mention special fields, such as literary history, or the

[1] *Cf.* Monod, G., *De la méthode dans les sciences* (première série), Paris, Alcan, 1920, pp. 376 f., article entitled "Histoire."

history of art, since these are not auxiliary sciences, but are merely historical procedure applied to certain kinds of classified source material.

The last two sciences mentioned, geography and ethnography, indicate the proximity of the field of historical study to that of natural science. Archeology also, when its remains must be dated in periods prior to the dawn of written history, shades off into biological science. It tries to trace human culture, as culture, back to its inception, keeping it separate from the biological factors all the while. The general science which lies in the borderland between biology and written history, which aims to bridge the gap between the biological story of the higher subhuman types and the beginning of written records, is called anthropology.

3. Anthropological Methods and the Preface to History

The general purpose of anthropology is to write the preface to history. Its aim is to determine the biological position of the human family in the group of mammals, to record the differences, both cultural and native, among the races of man, and to state, if possible, the causes of those differences. Anthropology is also a method, strictly speaking (what sciences are not!). But the fruits of it are primarily of historical significance; hence its treatment here. It also has psychological significance. It has thrown light on man's mental processes as well as upon his institutional life; indeed, it could be treated as a social science exclusively, if one stressed the study of contemporary aboriginal groups and slurred over the biological and archeological phases of it.

The prominent methods in the field of anthropology are as follows: the *biological* method, employing the theory of evolution and correlating races by their anatomical similarities; the *descriptive* method, aiming at the observation and description of different types of men and their cultures; the *archeological* method, the interpreting of prehistoric remains; the *philological* method, aiming at establishing historical connections by means of linguistic similarities; the *geographical* method, consisting of attempts to establish racial relationships and historical connections on the basis of distribution of metals, implements, languages, and arts; the *psychological* method, which attempts to interpret the culture of different races on the basis of the mental life which is apparent in language and various other habits of the people. All of these methods overlap; correct anthropological procedure is a fusion of as many of them as are relevant to the particular situation.

The achievements of anthropology have been too numerous to catalog in our restricted space. One of the simplest of these is a classification, using the biological method, of existing races of men: (1) the *black* races

(Negroid), characterized by dark skin, flat nose, kinky hair, large teeth, thick lips, prominent eyes, and narrow hips; (2) the *yellow* races (Mongolian), with yellowish skin, broad and prominent cheek-bones, narrow eyes with the typical fold at the inner corner of the upper lid, black straight hair, and teeth of moderate size; (3) the *white* races (Caucasian), with light skin, soft hair, narrow nose, small teeth, broad hips, and heavy beards. The scientific value of such a classification is very small, of course, and not to be compared with the significance of anthropological efforts to construct a history of early man. All the methods of anthropology have been employed in the effort to secure and piece together all the available evidence. The results, in part, may be sketched briefly.

In the Miocene, or early Pliocene period, climatic conditions in Asia, as a result of continental elevation and the shrinking of forests, forced man's subhuman ancestors from the trees.[2] With this change came the assumption of an erect posture, the varied and increased use of the hand, and an intensification of communal life. Since early man was physically weak, his best defense was found in running in packs and using his wits, such as they were.

An outstanding advance appears in *Pithecanthropus erectus,* the ape man discovered near Trinil, Java, in 1894 by Dubois. The remains were scanty, consisting only of a skull-cap, a thigh bone, and two teeth; enough, however, to indicate that here was an early type of man. The remains date from Pliocene or early Pleistocene times and indicate an erect posture and a somewhat human appearance. The bones of twenty kinds of mammals were found in the same strata, all of extinct species, pointing to a time not less than 500,000 years ago.[3] The cranial capacity of *Pithecanthropus* was about two-thirds that of contemporary man, approximately 985 cubic centimeters.[4] This is 350 cc. more than a gorilla, but 400 cc. less than an inferior contemporary human type such as the Bushman. No cultural remains were found with the bones.

The next important link in the story of early man's development is the Heidelberg jaw, discovered in 1907 under conditions indicating an age of at least 300,000 years. It was buried in sands laid down during the first or second interglacial period of Pleistocene times. Only a jaw and its teeth were recovered, but the teeth are human while the jaw lacks the typically

[2] *Cf.* Lull, R. S., *Organic Evolution,* New York, Macmillan, 1917, pp. 672 f. Also, Thomson, J. A., *The Outline of Science,* New York, Putnam, 1922, Vol. I, pp. 167 f.; and Romer, A. S., in *The Nature of the World and of Man,* University of Chicago Press, 1926, pp. 338 f.

[3] Thomson, J. A., *What is Man?* New York, Putnam, 1924, p. 13. *Cf.* MacCurdy, Geo. G., *Human Origins,* New York, Appleton, 1926, Vol. I, pp. 313 f.

[4] MacCurdy, *op. cit.,* p. 315.

human promontory of the chin. Some anthropologists hold that this jaw indicates a line of descent off the main path of man's evolution. Be that as it may, a transitional semi-human type of animal was living in North Europe in the first or second interglacial period. Very crude flint implements, or eoliths, were found near the jaw.

Another step is indicated by the Piltdown man found in Sussex, England, in 1912. The remains consisted of a skull (rather damaged by workmen in the extraction, but subsequently restored), indicating a large brain, without the protruding eyebrows, but with a jaw resembling a chimpanzee. Some investigators thought that the jaw did not belong to the skull, but the fragments of a second skull in the same gravels about two miles away, with a tooth of the same type found with the original remains, were convincing evidence. The cranial capacity of man evidently developed before the jaw and facial structures. Estimates as to the time of the deposits vary from 150,000 years upward.

The last of the lower types of man is *Homo neanderthalensis*. Neanderthal man takes his name from the ravine near Düsseldorf where the first discovery of this type of remains took place in 1856. The early finds were regarded as monsters rather than as links in the story of man's development. Even those who considered the Neanderthalers as a related species thought of them as off the main line of ascent. Other remains have been found in Belgium, France, and at Gibraltar; Neanderthal man's general characteristics have become well known. The cranial capacity was around 1500 cc. The body was loosely hung, a little over five feet high — the women were under five feet — with a long, low head and great beetling eyebrow ridges. The head hung forward and down on the chest, owing to the posterior position of the *foramen magnum,* and the curved thigh-bones indicate a semi-erect slouching gait. He was a true man, but the stamp of the ape was still upon him.

Recently Dr. Hrdlicka has raised a dissenting voice to the usual view that Neanderthal man is not an ancestor of *Homo sapiens*. Hrdlicka insists that the Neanderthalers are our ancestors. He holds that, instead of four distinct ice periods with three interglacial periods, there was but one main interglacial period, from which there was a gradual shift to an irregular cold period.[5] This was followed by irregular, warmer climate. Neanderthal man began to appear, according to Hrdlicka, toward the end of the long, warm, interglacial period, when the closing in of increasingly severe climatic conditions caused rapid selection and decrease of population. The great variability in the skeletal remains of Neanderthal man indicates the

[5] As given in *The New York Times* of November 9, 1927, in a report of the Huxley memorial lecture before the Royal Anthropological Society, in London, November 8, 1927.

relatively rapid changes which were going on, and it is simpler, according to him, to assume a continuity of development between this type and those following than to assume a double development followed by the abrupt extinction of one line of descent.[6]

Crô-Magnon man, named from the rock shelter in the village of Les Eyzies, Dordogne, France, is sufficiently like existing types to be classed as *Homo sapiens*.[7] One of the skeletons, that of an old man (the "old man of Crô-Magnon"), was estimated as that of a man five feet eleven inches in height and up to the average of contemporary races in cranial capacity. The women of this group were much shorter. The usual theory is that the type underwent development in Asia and came west to displace the Neanderthalers, only to be displaced in turn, along with the Grimaldi race (named from the Grimaldi caves near Mentone, Italy), by the incoming Neolithic men. These last, again, appear to have come from the east.

The cultural remains which have been found with the various forms of fossil man are classified carefully by the anthropologist. We can indicate very roughly, by diagram, the chief divisions of cultural materials and the types which are supposed to have produced them. (See opposite page.)

Long before we reach the year one A.D., in our outline of cultural remains, pre-history has ceased and history begun. Written records are available. With the appearance of these the chief problem of historical science emerges — the question of how to criticize documents.

4. The Historical Criticism of Records

The task of utilizing records is not an easy one. Just exactly how can scientific method be brought to bear upon the data with which historical science works? When confronted with ancient documents, such as Homer, the Egyptian *Book of the Dead*, or the books of the Bible, what can the historian do to reconstruct originals which have long since disappeared? This question of textual criticism is the first business of the student of documents. The rules which have been formulated for the handling of varying documents not available in the original are as follows: (1) Preference must be given to that reading which seems best to explain the variations which have arisen. (2) The most difficult readings are to be preferred

[6] Thomson, J. A., *Outlines of Science*, Vol. I, p. 169, takes the usual position when he says of Neanderthal man: "He disappeared with apparent suddenness (like some aboriginal races today) about the end of the Fourth Great Ice Age; but there is evidence that before he ceased to be there had emerged a successor rather than a descendant — the modern man." The usual view is that both Neanderthal man and succeeding types had a common ancestral stock in Asia (or Africa).

[7] MacCurdy, *op. cit.*, Vol. I, pp. 380 f.

TABLE V. A CHART OF PREHISTORY

YEARS (B.C.)	GEOLOGICAL TIME			LIVING FORMS		CULTURAL REMAINS (Following MacCurdy)
	QUATERNARY	Recent			Iron Age	100 B.C.—year 1
						300 B.C.—100 B.C.
						500 B.C.—300 B.C. Antennae swords and poniards Long swords of both bronze and iron
5,000?					Bronze Age	Winged and end-socket axes Axes with transverse ridges Plain-border axes Flat axes
					Neolithic	Carnacian { Stone cist; Many-chambered dolmen; Small dolmen }
10,000?						Robenhausian — Polished flint implements
				Living races		Campignian — Pottery
						Meglamosean
						Azilian-Tardenoisian — Painted pebbles, harpoons of staghorn
		Post Glacial Period	Daun		Paleolithic (Old Stone Age)	Magdalenian { Evolution of harpoon of reindeer horn; Polychrome frescoes; Evolution of the javelin }
25,000?			Gschnitz	Crô-Magnon		
			Bühl			Solutrean { Point with lateral notch at base; Laurel-leaf point; Font-Robert point }
						Aurignacian { Art; Graver; Scratcher } (Transition)
		Pleistocene or Glacial Age	Würm	Crô-Magnon Grimaldi		Mousterian, Acheulian, Chellean — Evolution of the cleaver and scraper
100,000?				Neanderthal		
			Riss	Piltdown	Eolithic	Pre-Chellean?
500,000?			Mindel	Heidelberg		
1,000,000?			Günz	Pithecanthropus		
	Tertiary (Pliocene)					Eolithic? First attempts at use of tools.

to the easier ones, since the tendency of a copyist is to simplify. (3) Preference must be given to the reading most consonant with the context, style, and probable date of the work.

When the best possible text has been achieved, the understanding of the full significance of the document, as reconstructed, is the goal of the historian. This involves the so-called "higher," or literary, criticism. The following questions are always involved in some form in the careful literary criticism of a document: (1) What is the *historical background* of the work? It is impossible to understand an author's meaning apart from the events he is handling. (2) What is the *specific occasion* of the work? Why did *this* author write *this* document? (3) What is its *authenticity?* Was it written by the man whose name is attached, or who speaks of himself as author in the text? (4) What about the *integrity* of the work? Is it intact, as the work of a single author, or is it composite? Has it been edited, and, if so, how much? (5) What is its *credibility?* Are we to believe what the author says? Did *he* believe it? Did the author know what he was talking about? Did he state what he knew, and if not, why not? (6) How does the material in the document *accord with other evidences,* such as monuments and archeological remains? Can we predict from one to the other, *i.e.,* is it "what one would expect," knowing the other relevant cultural remains? (7) What about the *style* of the work? Is it poetry or prose, historical, didactic, dramatic, homiletical, or what not?

A good field of illustration is found in the criticism of the books of the Bible. Take, for instance, the book of *Daniel,* a work purporting to have been written in the sixth century B.C., in Babylon, by a man who calls himself by the name Daniel. A vast machinery of criticism is necessary merely to date the book, apart from the detailed interpretation of it verse by verse.[8] As it happens, this particular document can be very accurately dated. We know the date of its writing almost to a month. The author of *Daniel* knew history up to December, 165 B.C., but knew nothing which happened after May, 164. The book as a whole probably dates, therefore, from early in 164 B.C.

The reasons for giving *Daniel* this late date may suggest the immensity of the historian's task of criticism: (1) The position of *Daniel* in the Hebrew canon, next to the last, indicates that it came late. (2) Jesus ben Sirach, who flourished about 200 B.C., is silent as to *Daniel,* although he comments freely on other books. (3) Nebuchadnezzar did not besiege Jerusalem and carry away sacred vessels in the third year of Jehoiakim (605 B.C.), as stated in *Daniel* I: 1. He did not ascend the throne until

[8] *Cf.* Charles, R. H., "Daniel," in *The New Century Bible,* Oxford University Press.

604 B.C. No writer contemporary with the events would have made such an error. (4) The word " Chaldean " is used in the work in the sense of " wise man," or magician, a late usage and an impossible one in ancient Chaldea, where everyone was a Chaldean. (5) Belshazzar was not the son of Nebuchadnezzar, as the book states, nor was he ever king of Babylon. (6) There was no " Darius the Mede," as mentioned in *Daniel,* who received the kingdom and ruled over the Chaldeans. (7) *Daniel* IX: 2 says that Daniel understood " the books," *i.e.,* the holy books (the canon). This would mean that he understood the canon before it was organized, and that *Jeremiah* was in the canon in Jeremiah's day! (8) *Daniel* IV: 8 gives an incorrect explanation of the name " Belteshazzar." (9) Persian words are found in the text, indicating a date at least after the Persian occupation. (10) The names of Greek musical instruments are used, indicating a date after Alexander's invasion. (11) The Aramaic of *Daniel* is Palestinian and not eastern. (12) The Hebrew of *Daniel* is late, similar to *Esther, Ecclesiastes,* and *Chronicles.* (13) " Nebuchad*n*ezzar " is not the correct form of the king's name. His name was Nebuchad*r*ezzar. (14) The theology of *Daniel* is late, involving the resurrection, angels, judgment, and the notion of the kingdom of Jehovah. (15) The interest of the book is in the time of Antiochus Epiphanes, a time not likely to be revealed to " Daniel " four centuries before in Babylon. (16) Up to *Daniel* XI: 39 the predictions are accurate. After that verse, which refers to the period just before the death of Antiochus in 164 B.C., all the predictions are erroneous.

The book, therefore, after detailed criticism, can be dated before the rededication of the Jewish temple in December, 165 B.C., at all events before the death of Antiochus, and it must have been written after the desecration of the temple by the Syrians in 168 B.C. The book is to be regarded, probably, as war propaganda passed about among the Jewish soldiers under the Maccabees. This explains the marvelous tales it contains. Without the elaborate machinery of criticism, however, the historian is as powerless before such a document as a physician attempting to treat typhoid fever without the science of bacteriology.

An illustration of the way in which accretions accumulated, in ancient days, as a result of the repetition of an account, is brought out frequently by a simple paralleling of the materials. The following are the accounts of the wounding of a man present at the arrest of Jesus, as given in *Mark* (the oldest account), *Matthew,* and *Luke.*[9]

[9] *Huck's Synopsis of the First Three Gospels,* arranged by Finney, Ross, L., New York, Eaton and Mains, 1907, p. 136.

Mark XIV: 47	*Matthew XXVI: 51–54*	*Luke XXII: 50, 51*
But a certain one of them that stood by drew his sword and smote the servant of the high priest and struck off his ear.	And behold, one of them that were with Jesus, stretched out his hand, and drew his sword, and smote the servant of the high priest, and struck off his ear. Then said Jesus unto him, Put up again thy sword into its place: for all they that take the sword shall perish with the sword. Or thinkest thou that I cannot beseech my Father, and he shall even now send me more than twelve legions of angels? How then should the scriptures be fulfilled, that thus it must be?	And a certain one of them smote the servant of the high priest, and struck off his right ear. But Jesus answered and said, Suffer ye them thus far. And he touched his ear, and healed him.

Luke is not content merely to add a speech, as does Matthew, but he says it was the " right " ear, and he has Jesus perform a miracle of healing on the spot! There is no evidence that he had access to any more specific record of the events than did the earlier author of *Mark.* Both the addition of speeches and the enhancing of dramatic situations, however, are commonplace matters to students of ancient documents.[10]

One of the most important of ancient records, a stone inscription instead of a document, is easily accessible to all visitors in London. Enter the British Museum, go down the long corridor to the left, and then turn right into the Egyptian rooms, and straight ahead, tilted at a convenient readable angle, is the famous Rosetta Stone. The discovery of this piece of black basalt, by French engineering troops digging in 1799 near the Rosetta mouth of the Nile, opened the way to the development of Egyptology. On the face of the stone are parts of three equivalent inscriptions, one in hieroglyphics, another in demotic characters, and the third in Greek, indicating that it was erected in honor of Ptolemy V (Epiphanes) March 27, 196 B.C. This stone furnished the key to the understanding of Egyptian hieroglyphics,[11] and is an historical record of the first importance.

It is simpler to handle modern records than ancient ones, if only because written materials, found in the original, eliminate the necessity for elaborate textual reconstruction. However, the same critical principles

[10] *Cf.* Lucian, *Vera Historia,* for a satire on ancient history by a near contemporary.

[11] Much of the work was done by J. F. Champollion (1790–1832); also T. Young (1743–1829).

must be followed as the constant checking of one record against another is carried on. The present writer happens to have in his possession an original document of historical significance in American history which is intrinsically interesting and, at the same time, illustrative of the raw materials from which our histories are constructed. The document is a letter from one Henry Bailey of Providence, Rhode Island, to the Hon. Sampson Perkins, of New Bedford, Massachusetts, written in 1842. It was secured from Mr. Herbert A. Wilcox, of South Pasadena, California, who is distantly related to the recipient of the letter. It reads as follows: [12]

Providence, May 2d, 1842

Dear Sir,

We are having rather a squally time of it here in little Rhode Island in relation to our State Government. The question is have the People the power to change their form of Government without the consent of the Legislature. In order for this question to be properly understood I will give you the outlines of the present form. This State has the Charter of King Charles the 2d for its form of government which gives to the Legislature the power to admit as many or as few to the right of the election franchise as they may see fit or in other words to make or unmake the People at its will and pleasure. According to the present law (which has not been altered materially since the Revolution) no Man can vote unless he owns $134 worth of land or is the eldest Son of such a landholder and not then untill he has produced his deed in open Town Meeting and then stood proponded 3 month and voted in by a majority of freeman present. The eldest Son can vote as soon as his father is admitted fre[e] although he may be the biggest scamp on earth whilst his younger bretheren are denied this privelege most dear to an American Citizen. The Charter also fixes the representation of the different Towns it gives to Newport 6 representative whilst it only has 8000 inhabitants Pourtsmouth 4 with 1700 — Jamestown 2 with 300 and the same in most of the Towns in the South part of the State whilst in the North, Providence with 25000 has 4 Smithfield with 9000 2 and so in most of the North Towns. It is to this feature in the Government that has kept the State so long under the Charter. The South part of the State well knew that if we had an extension of Suffrage we should also have an equaliasation of representation and she by having so much of the advantage in the government has determined never to yeild it untill [it] was wrenched from her. The law admiting freemen when it was first made was not very unjust for almost all owend land but times have materially changed. Our Territory is small and our State is thickly populated a large proportion of the inhabitants are engaged in Mechanical and Manufactoring pursuits and by the last census we found that we had 26000 inhabitants over 21 whilst the largest vote ever poled was about 8000 consequently a large majority were disfranchised. The People have often petitioned the government for a redress of grievances and have as often been refused. The Legislature have called two Conventions for the

[12] A few emendations have been made in addition to those indicated.

purpose of framing a constitution but the inequality of the representation in that body a majority of them chosen by less than one ninth of the inhabitants in the South part of the State they never could frame any instrument that the freeman would adopt. In order to carry out their proscriptive Government they have enacted laws that are very oppressive to the Non freeholder none of them are eligible to any office not even to a Flog weve nor can they sue a man in a court of law unless they can get a free holder to back them ( ) for them although they may be worth $50,000 and have to pay taxes on every cent of it they have refused to admit us as freemen but have not forgot to tax us to the utmost farthing. Personal property pays the whole expenses of the State government and consequently the Non freemen have to pay a good proportion of it. A year ago last March some five or six Mechanicks of this City after talking over the subject concluded to call a meeting to see if anything could be done. The first meeting about twenty attended they adjourned from time [to] time each one more fully attended untill it was thought advisable to form an Association. We did so and called uppon the other Towns to do likewise a number of Associations was formed in diferent sections of the State. The Presidential Contest soon came on everything was absorbed in that and we laid over untill it had subsided when the contest was over we again renewed our meeting held them through the Winter and established a weekly Paper to advocate our cause. In February [18] 41 the Rhode Island Association put forth its principles and passed some resolutions which [were] agreed to by the other Associations of the State. One of the resolutions read this Resolved — That whenever the People of this State shall by their delegates assembled form a Constitution and the same shall be approved by majority of its citizens it will then become to all intents and purposes the law of the state. In April of the same year we had a mass meeting in this Citty there was about 4000 persons present they called uppon the Citizens of the State to assemble in mass at Newport in May to take some action upon the subject. A large meeting of Citizens convened according to the call they appointed a State Committee of eleven persons and instructed them to call uppon the People of the diferent towns to elect delegates to attend a convention to frame a Constitution the meeting in Newport adjourned to meet in Providence on the 5th of July. The meeting was accordingly held about 8000 persons were present they again reinstructed their committee. Soon after the committee issued the call for all persons who were 21 years old and who had resided in the State one year to meet in their respective Towns and chose their delegates one delegate to every thousand inhabitants. The people assembled chose their delegates they met formed the Constitution appointed the time for the people to vote on it at the time appointed 14000 polled their votes for the instrument the Convention met declared the Constitution to be adopted. The Landholders in the meantime assembled they saw how the thing was a going they must now make an attempt to head us off they proposed a Constitution and fixed a liberal

extension and allowed all to vote for or against it that were allowed to vote under it. The People went to the Polls and voted it down for the following reasons viz. 1st They had already voted for a constitution which suited them and which they believed the people had a right to make without the consent of the Legislature inasmuch *as there is no mode pointed out in the Charter or laws of this State how the government shall be altered or amended.* 2d. When the People asked the Legislature to be admitted to the right of voting for delegates to that convention they were REFUSED. 3d. Their Constitution contained the old rotton borough systim of Representation Less than one third of the inhabitants choosing a majority of the Senate 30,000 having the same voice as 78,000. 4th. It made three or four classes of voters and also it open the way for great frauds to be practised under it for these and many other reasons the People rejected it although every effort was made to adopt it and that to by pe[rsons] who did not like it their only object being to defeat the will of the People. After it was rejected the Legislature met and passed a law of pains and penelties for any Man to suffer his name to be used for a candidate for any office under the Constitution or to act as Moderator or Clerk of any Meeting and sent on to Washington for the President to send an armed force to put us down. Many Men who were anxious to take office when things went smooth BACKED OUT when trouble come but thank God there were enough who had firmness enough to stand and are elected. I think [I] know well your feeling for such men who cry loudest when things go smooth but when the trouble comes *will like Peter deny their Master.* Next Tuesday is the day for organization of the government under the Constitution in this Citty and Wendesday they meet under the old Charter in Newport. The old Charter folks have made 10,000 ball Cartridges for the purpose of shooting the People Whilst the People are preparing themselves for any emergency. I have spent all day to day Sunday making Ball Cartriges. What will be the result God only knows we however hope for the best.

Yours etc.
Henry Bailey.

Such primary sources as the above letter are organized by the historian into a connected narrative.

The following, written in 1904 for *The Encyclopedia Americana* (article "Rhode Island") by Edward Field, is a sample of the secondary sources on the Dorr Rebellion, in which the writer of our letter participated as one of the rebels:

The charter of Charles II, which continued to be the fundamental law of the State, restricted the right of suffrage to freeholders having an estate worth $134, or renting for $7 a year, and to their eldest sons. This was the cause of many wrongs, and of widespread popular protest. It was not uncommon for persons holding mortgages to threaten to foreclose them in

> order to influence votes, and the system gave rise to much intimidation and corruption. The conservative element strongly opposed a change, and when attempts to obtain reform through the regular course of legislation failed, representatives of the suffrage reform party met in convention and framed a constitution. They claimed that this constitution had been adopted by a majority of the adult male citizens of the State, and it was also alleged that a majority of those entitled to vote under the King Charles Charter had voted in favor of the constitution. State officers and a legislature were chosen under this constitution, and organized with Thomas W. Dorr as governor. The charter officials, under Governor Samuel W. King, ignored the Dorr legislature and its enactments, and Governor King, at the head of a military force, dispersed the so-called insurgents. Dorr was convicted of treason, and sentenced to imprisonment for life, but he was released some years later, and his sentence ordered expunged from the records of the State. A new constitution was adopted in regular form, and went into effect in May, 1843. It retained the real-estate qualification for foreign-born citizens, and this was not abolished until 1888.

This excerpt reminds us of history textbooks which are, of course, secondary historical sources largely composed, by their writers, from previously organized secondary sources. Only historical *research* concerns itself with primary sources.

We pass now to a survey of some of the typical efforts to extract from human records a " law " of history by means of which the succeeding steps in human affairs possibly may be predicted.

5. Some Philosophies of History

One of the outstanding attempts to develop a philosophical theory of history was that of G. W. F. Hegel (1770–1831). His *Philosophy of History*[13] was a development of his notion that a " universal spirit " (*Geist*) was gradually revealing itself in history. He distinguishes levels of revelation of the " absolute idea " and follows the dialectic of his logical theory in outlining the stages of development: the Oriental, Greek, Roman, and German. The universal spirit passes from state to state in its march through history. An immanent metaphysical plan is revealing itself in history and culminating in the greatness of Germanic culture. For, like most other philosophies of history, Hegel's theory places his own day and civilization at the apex of the scheme of development. He says: " The history of the world is the discipline of the uncontrolled natural will, bringing it into obedience to a universal principle and conferring subjective freedom.

[13] Hegel, G. W. F., *Philosophy of History*, trans. by J. Sibree, New York, Collier, 1901.

The East knew and to the present day knows only that *one* is free; the Greek and Roman world, that *some* are free; the German world knows that *all* are free. The first political form therefore which we observe in History is *despotism,* the second *democracy* and *aristocracy,* the third *monarchy.*" [14] It took a good imagination to see an incarnation of a " world spirit " in the stodgy German princelings on the Prussian throne of the 1820's, but Hegel was equal to the task! His whole social position, and his apotheosis of the state, was to be understood, of course, with the successful Prussian state in the background.

There was a widespread interest in history in the early decades of the nineteenth century. Partly contemporaneous with the development of German idealistic philosophy (by Fichte, Hegel, and others), and partly subsequent to it, the historical method was applied to various institutions with a strong emphasis upon national interests. Hegel wrote not only a philosophy of history but one of art and of religion; historical arts and religions figured in their respective niches in his system. The Tübingen school of Biblical criticism, furthermore, received its inspiration from him. F. K. Savigny (1779–1861), a contemporary of Hegel, was one of the founders of historical jurisprudence. The Romanticists in literature also had historical interests. They, too, liked old things; the instincts, feelings, and intuitions of the earlier ages appealed to them. Most of them joined the Roman Catholic Church before they died. The interest in former days extended to language. One of the Grimm brothers, Jakob Grimm (1785–1863), was an inventor of Grimm's law and a writer of folk stories, as well as a collector of German legal antiquities. The Grimms had much to do with the emergence of *philology,* the science of language, which took its rise in Germany from 1790 to 1830. The nationalistic motive was strong. Language and law, and other institutions, were thought of as historical emergences which were nationally characteristic. They were involuntary emanations of the nation's mind, so to speak, expressions of a collective psychic activity which had laws of its own. This notion led eventually to the development of folk-psychology, which was imitated in France by such schools as that of E. Durkheim, who holds that ideas arise in corporate activity. Immediate repercussions of the historical interest in Germany were in evidence in France, however, in the form of other philosophies of history.

Victor Cousin (French, 1792–1867), in his eclectic spiritualism, followed Hegel in sketching a philosophy of history on a dialectical schematism. Each age or nation incarnates a single idea. The notion of the *infinite* (in oriental nations) was succeeded in history by that of the *finite* (Greek); his own age represented, in his opinion, the combination of

[14] *Idem,* p. 164.

finite and *infinite*. What can one predict from such a formula? No ideas are left for America or Australia! And, if the theory were true, as Flint says,[15] a " monomaniac nation " is even more dangerous than an individual whose wits are tainted in this fashion!

Auguste Comte (1798–1857) is reported to have remarked that there were one hundred and twelve philosophies of the state, and that all of them were false. He proceeded to write the one hundred and thirteenth! While there were not that many philosophies of history prior to Comte, he wrote another of these also. According to him, history shows three definite levels. The first stage is the *theological* period. In this period, all phenomena of nature are thought of as produced by the immediate action of superhuman beings. Control of nature is attempted through influencing the wills of quasi-spiritual beings. This period culminates in monotheism. In the second or *metaphysical* stage, substances are substituted for gods, and " nature " comes to be the dominant principle. Man seeks to secure his well-being through controlling the forces of nature, and explanation culminates in a vast system of " Nature." The third period is *positivistic*. In this stage laws, rather than gods or substances, are studied. Explanation is effected by the discovery of constant relations among phenomena. This third period culminates in the recognition of a supreme fact or entity. As Comte worked out his full doctrine, he stated, for the first time in history, the general problem of the reorganization of men's beliefs, as well as the reorganization of social conditions, in terms of scientific development. His contribution was immense. But what can be predicted from such a formulation? How can one tell what the next stage will be?

A great many other philosophies of history or generalizations of historical " law " have been written with varying emphases.[16] The theory that historical events have been the function of economic factors, the " economic interpretation of history," is very popular. In the employment of this philosophy of history, extremists have reduced art, religion, and science to economic terms. Insofar as economic factors had been neglected by prior historians this new emphasis has been wholesome. Social life would not be what it is were economic factors abstracted from it. But an adequate history is more than antique economics, as an adequate psychology is more than a discussion of sex. At one level of its employment the economic interpretation of history is a truism; at another it becomes a *reductio ad absurdum*, and ends by being as misleading as any other theory can be which is overworked.

The chief value in studying philosophies of history is that they enlarge

[15] Flint, Robert, *History of the Philosophy of History in France and Germany*, New York, Scribners, 1894, pp. 192 f.

[16] The theories of Herbert Spencer and of Karl Marx have been very influential.

the imagination! All of them falsify the facts by oversimplifying them, and none of them is of any use in predicting succeeding stages in the various human developments. They are so general as to be meaningless. When we try to get specific predictions with reference to particular materials, they turn out to be available only in terms of other sciences, in which controlled experimentation is usable as a method. The philosophies of history were, of course, attempts at social science; they were not history in the strict sense. As social science they were and are failures.

History, as we have said, is the interpretation of human records. It composes, from its piecemeal evidences, a story of man's past. But its predictions have to do only with records. Its generalizations have to do with the arrangements of documents and their contents, not with the destiny of man. The " laws " of historical science are the rules which are found applicable to human records, the generalizations which connect such predictions as are possible from record to record. The actualization of human events is not history's subject-matter, nor is time, as such, the province of the historian. History does not study the dynamics of human change, but the meaning of human remains. By definition the past cannot be an event, and the subject-matter of history is not the events of the past but records of them.

We repeat, history is not a fabric of past events, but of the records of past events, and its rules apply to those records, which are its only materials. *The historical fact or event, as such, is a record.* But the record of man's future is still to be written, and it cannot be written until it has happened. A *philosophy of history,* in the proper sense of the word, is not an attempt to predict, from a few scattering records, a human destiny of which nothing really is known, but is a criticism of the techniques of historical procedure.

As an auxiliary to social science history is invaluable, but any suggestions for social science which can be extracted from history have only such scientific validity as they turn out *experimentally* to possess.

P. W. W.

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CHAPTER VII

THE SOCIAL SCIENCES

1. Introductory

In a famous passage Plato states the importance of intelligence in social affairs:

> Until philosophers are kings, or the kings and princes of this world have the spirit and power of philosophy, and political greatness and wisdom meet in one, and those commoner natures who pursue either to the exclusion of the other are compelled to stand aside, cities will never have rest from their evils, — no, nor the human race, as I believe — and then only will this our State have a possibility of life and behold the light of day.[1]

" Philosopher " in ancient Greece meant a lover of wisdom — an educated man. The ideal which Plato expresses, that the wise should rule, has never been attained. The power of deep and continuous reflection has been given to few, and they have never governed mankind. But the aim of enlightened leadership is one which man can never give up and, since the development of modern democracies, the goal has broadened to include an enlightened citizenship. For this reason, if for none other, the study of social science is important. Let us first look at some of the general terms used in this field.

(*a*) Terms Used in Social Science. — The term *politics* has had a long career. The Greek city-state was called a πόλις, whence came πολιτικός and the Latin *politicus*. Politics was the inclusive term used by the ancients for the general science of social affairs. In modern usage this term has narrowed to an exclusive reference; political science has to do with the structure and function of the *coercive* organizations of society.

The term *economics* also goes back to the Greek. It is derived from the word meaning *house* or *home*. Aristotle wrote an *Economics,* but it contained material which we should classify today under the head of household management. The contemporary science of economics dates from the French Physiocrats of the eighteenth century, and from Adam Smith, Ricardo, and others, who centered their social philosophizing around questions of industry and wealth. *Political economy* was the name under which it first separated from the general field of political or social theory. Now economics is studied as a field distinct from political science, and a third discipline called *sociology* must be distinguished from both of them.

[1] Plato, *Republic,* Bk. V. (Jowett's translation).

Sociology, as a separate science, was developed by Auguste Comte, the French philosopher who popularized the term. Comte's work took place in the second quarter of the nineteenth century. Herbert Spencer, whose chief productivity fell in the third quarter of the century, aided greatly the establishment of a separate body of doctrine under the head "sociology." With economics already discussing business and industry, and government treated by political science, sociology found much of the field of social science already preëmpted. However, it claimed to discuss the general laws governing all social developments whatsoever, and it has gradually won a certain recognition as the body of knowledge having to do with the more general conditions of all human associations.

Both the history and the contemporary state of the social sciences give evidence of confusion. The main divisions of social science have arisen as the result of different emphases and viewpoints on the part of the workers in the field. Great overlapping is apparent, both in the past and at present. Economic interests intrude into politics. Political structures are utilized in economics, and sociology would give a queer picture of society, indeed, if it described it minus all business, industry, and government. Nowadays every well-trained worker in any social field regards himself as primarily a *social scientist*.

(*b*) Does Social Science Exist? — But is there such a thing as social science? This is a question frequently asked, and when it is put by a worker in the natural sciences (physical and biological), it is almost always rhetorical in character. The avowed implication is that science is non-existent in social affairs. The psychologist, also, is likely to speak of social science with a smile. The fundamental criticism which other scientific workers make of the social sciences has to do with the nature of science. They are consciously seeking, in their own provinces, formulas which give accuracy of prediction and, if this is possible, control. Where, they say, does the social scientist predict accurately? What forecasts can he make which turn out to be correct? In terms of his formulas, what controls does he set up? Does political science improve man's life by giving him any genuine control over his public affairs? Does sociology enable him to predict and control his future development? Does economics enable him to master the conditions of a more tolerable life? No, they say, where useful knowledge is available for social purposes, it is not social knowledge but physical, biological, or psychological science. This is the core of the criticism. The point is that all social phenomena are *primarily* something else and only secondarily are they social. Prices of food and clothing are functions of biological or psychological needs. Social developments are functions of biological, geographical, and historical factors. So, the argument continues, when you want to predict and control — when the *science*

of the matter is aimed at — you must go to physics, biology, and psychology to get the laws with which to work. To speak of "social laws" is to talk merely of the surface of events. The real factors in the field are biological propensities in their environment or, to put it psychologically, man's nature and his habits or previous conditionings by the environment.

This criticism has a grip. If we sample the predictions in political affairs, we see at once what is meant. To predict the result of an election is difficult, but not impossible. But prediction is not possible merely in terms of our knowledge of the structure of the American government. Political science, as traditionally studied, is as powerless to predict the result of an election as is the science of anatomy to forecast the career of a case of diphtheria. A knowledge of the functioning of the electoral college, for example, does not enable one to predict *which* party will elect. But in terms of the habitual drives and the contemporary interests of the voters a prediction is possible. The results of the national election of 1924 were conceded almost universally by those who had studied the situation. Since the Civil War the American people had been habitually Republican. "Prosperity," furthermore, was in evidence in 1924. Habit and inertia pointed to a continuation of Republican control of the national government. In addition, the Democratic Party was split in several ways. The South was economically conservative, dry, and Protestant. The North was economically more radical, moist if not actually wet, and, in large measure, Roman Catholic. In terms of a *psychological* analysis of the interests concerned the result was predictable. But the generalizations in terms of which such a prediction was possible were primarily psychological in nature. Although the *what* is furnished by the social situation, for the *why* and the *how* we tend to go to other fields.

Social scientists will admit that, if science is defined narrowly as discourse which yields exact predictions and controls, they have little to offer which is genuinely scientific. But there is much more to be said on the subject. Social science, for one thing, has never been given the systematic development which other sciences, such as physics, have undergone. True enough, it was cultivated by the Greeks. But modern civilization has been almost exclusively technical in character. Physics, chemistry, and, later, biology have been cultivated intensively. Aristotle's analysis of the Greek city-state remains as one of the most up-to-date scientific studies in social science, while his *Physics* is hopelessly obsolete.

To say that there is little social science is one thing; to say that there can be none is another. The former is, perhaps, true. The latter is not at all evident. That more social science is not available by way of knowledge is, perhaps, a historical accident rather than anything else. Comte thought that a genuine social science had to await the development of the other

sciences as a precondition of its own appearance. At all events, most of the criticisms of the social sciences turn out, upon careful analysis, to be assertions of their backwardness. Furthermore, the World War has demonstrated that their backwardness has fatal consequences. The institutions of contemporary society are, for the most part, the results of a series of historical accidents, excepting as biological structures and activities have laid down the framework of possibility. Even the biological factors are alterable, of course. A mature biology coupled with a mature social science would enable man to remake both his own nature (unlearned activities) and that of his civilization (learned activities). The possibilities are evident, but we are ignorant, and nothing is to be gained by pretending to be wise.

2. The Methods and Aims of Social Science

The methods by which men have tried to work out satisfactory knowledge of their social life have been various. Some of them are so obvious that a mere mention of them is sufficient. Man is an animal. Hence, his life history naturally falls within the limits laid down by the framework of *biological knowledge*. Whereas ancient science sometimes regarded man as " a little lower than the angels," modern science regards him as a little higher than the apes. Moreover, biology not only furnishes the rough outlines of his present possibilities, but also an historical account of his genesis, which merges into the problems involved in the origins of other living species. Anthropology, as we have seen, tries to solve the problem of man's primitive life and culture. Its location on the borderline between biology and history is significant; it is the biological method supplementing history or the historical purpose animating biology. Its aim is to enlarge the account of man's past which is available as history.

History is the organized field of knowledge most conspicuously utilized in the past by social scientists. What man has been and has done is carefully conned over in an effort to comprehend the present orderings of his society and to anticipate his future groupings. Political theorists such as Aristotle and Machiavelli, indeed all the more influential political thinkers up to the present day, have made abundant use of history, while a contemporary sociologist, Durkheim, frankly takes the position that sociology is, in large part, a species of history understood in a certain way.[2]

The *psychological method* is also important in social science. Its value has been emphasized by the large crop of social psychologies written in the last twenty years. It is obvious that the knowledge of human instinct and habit, emotion and intelligence, in their various forms, is fundamental to

[2] Durkheim, E., in *De la méthode dans les sciences* (première série), Paris, Alcan, 1920, p. 329. Article entitled " Sociologie et sciences sociales."

an understanding of human organizations. Human nature is the stuff of which society is made and, apart from the complete science of human nature, social science always will be, in some sense, guesswork. A more adequate social science awaits a more developed psychology. The psychological method has been used since the days of ancient Greece. Plato and Aristotle wrote of habit and character, feeling and thought, and out of their notions concerning these things emerged their ethical and social theories. Hobbes, Spinoza, and Locke used, as indeed every political and social theorist has used, a psychology of human nature. True enough, many times the psychology has been unacknowledged, but psychological presumptions, either consciously or unconsciously, have always influenced social thinkers.

This last method, the psychological approach to social events, coalesces very easily with the historical method. Take history, and play upon the motif of human passions, explain the past changes by the shifting of human motives and the alterations in human conduct, and a more human history emerges. Strictly speaking, the historical method is not complete until, in the account of the past the characters of other days are made anew to strut and fret their former lives as genuine human beings, rather than mere puppets. By thoroughly illuminating the past, history, with a liberal spicing of psychology, can make us more aware of our present strengths and weaknesses.

The great defect of the techniques of social science is the lack of the *experimental method.* To call attention to the dependence upon history is merely another way of saying that experimentation is not prominent in social science. But how can one ever be sure that any occurrence, or series of occurrences, is in any particular degree *typical?* Apart from experimental control, how can one verify precisely any social theory? In general social science has taken refuge in the *comparative method,* which is essentially descriptive, as is history. Cultures are compared contemporarily as well as placed serially, as in the historical method. And we have university courses in comparative government, comparative education, comparative religion, etc. If the social sciences could deliberately experiment, they could advance rapidly. A prominent factor in the remarkable social knowledge of the ancient Greeks was the fact that the Greek city-states furnished, in their minute and rapid, almost kaleidoscopic, changes, as close an approximation to laboratory experimentation as we have seen. Many of Plato's students in the Lyceum were called upon to go out and write constitutions and rule cities. Plato himself tried his hand, with well-known results, at Syracuse. The desirability of the experimental method is clear, but the difficulties in the way of its adoption are equally apparent.

When the comparative method is used with mathematical exactness, the *statistical method* is employed. The factors to be compared are isolated

and controlled sufficiently to allow for measurement, and comparisons are then based upon these. Specific prediction with reference to the individual is not effected, but correlations are group predictions. That is, the particular aspect of the group which is isolated for measurement is sufficiently determined to give it a generic fixity — statistical ratios, or laws, are stated. When we say that the human life-span is fifty-eight years, we do not mean to say that John Doe will die at that age. He may die at the age of two weeks or at ninety-nine years and six months. We mean that the particular group, in its dying, has succeeded in postponing the fatal day, *on the average*, for fifty-eight years. That means something with reference to the whole mass involved, or any typical portion of it — enough, at all events, to make possible the existence of insurance companies. Statistics fixes on one aspect of many individuals and tries to achieve prediction with reference to that one item, and does not attempt exhaustively to measure many aspects of one individual and to control the conditions in a specific situation, as is done in the experimental techniques of physics.

Contrast a group psychological test, for example, with the recent experiments on the cathode ray.[3] In the one case the goal is the measurement of one aspect of many individuals, in the other the determining of all possible aspects of the one thing — the cathode ray. The resulting knowledge is radically different; what this cathode ray does in this situation, *any* cathode ray will do in *any* situation similar in character, but although Mr. Average Man may have an intelligence quotient of 100 and die at the age of 58 years, in any large group there may be no one who has exactly 100 for an I.Q. or who folds his arms and dies at exactly 58 years of age. But prediction is so important that any discourse which yields it, however meagerly, is cultivated intensively.

3. What is an Institution?

The importance of psychology in social science is well brought out by any attempt to define a social institution. Is there any reality which is social, as such? What, precisely, is the subject-matter of social knowledge? If there is no subject-matter, there is no science, for there is nothing to be known. A subject-matter must both exist, and be identified, before there can be a science of it.

The realities with which social science is primarily concerned are the activities of human beings having consequences which are widespread in their effects, *i.e.*, affecting others.[4] The subject-matter of social science is all matter of "public interest," or "public affairs." And a *public* affair

[3] See Chapter IX, page 186.

[4] *Cf.* Dewey, John, *The Public and Its Problems*, New York, Holt, 1927, Ch. I.

is distinguished from others by the extent of the consequences involved, and by no other criterion. A public affair is one affecting a public, and a public is the group affected by the act in question. To say this is not to travel in a circle but to indicate that there are varying degrees of public interest, that various acts have their various publics which are affected. Apart from the interrelations of human beings, and the fact that we are involved in the consequences of each others' acts, there would be no matters of public interest and therefore no social science. *The problem of social science is to envisage clearly the consequences of our conjoint activity and to take care of those consequences.* If only one man were left in the world, he could have his astronomy, physics, chemistry, biology, and psychology. But there would be no public, and, therefore, no social science.

Where our activities are grooved or channelled in character they are called institutions. *An institution is a public habit.* As such, it is of prime interest to social scientists. It is the chief subject-matter of their science. Specific acts, of course, such as the assassination at Sarajevo, because of their widespread repercussions upon other habitual activities of men, may assume dramatic public or social significance. Whether institutionalized or variant conduct is involved, it is the consequences which determine whether or not the activity is of public interest. All action is specific; but some is institutionalized and some is not.

We must not forget that the lines we draw between the sciences are merely matters of convenience. But they *are* matters of convenience and must not mix us up. We assign to biology the study of nutrition, reproduction, respiration, blood circulation, etc., *as such.* To psychology go our conscious and near-conscious activities — emotion, perception, memory, reasoning, etc., again *as such.* To social science belongs the whole context of human acts which significantly affect other acts. Any shift of human activity, or of environmental structure for that matter, which affects the habitual organization of man's life activities may legitimately come within the scope of social science.

Although we must base a treatment of social institutions upon biology, since man is an animal, psychology is the science which affords the best notions for conceiving these social structures. For contemporary institutions have much artifice about them. Men's habits have developed out of their basic needs and native responses, but they have *developed,* and the notion of an institution is the idea of a body of action, not native in character, into which the young must be initiated. Our civilization, in its various departments, is society thought of as an institution. Nurture has its patterns as well as nature, and the relative fixity of the latter does not involve the fixity of the former. Our culture develops as activities change and fuse. Institutions are the nodes or foci of our activities, departmental-

ized as they are, and having places and times at which they ordinarily take place. It is the business of social science to describe *what* these are and *why* and *how* they change.

4. The Family

For purposes even of the description of institutions, not to mention prediction and control, it is necessary, as we have already suggested, to go down through psychology to biology. Human activities are living functions. Biology studies reproduction; psychology studies the emotions and instinctive drives of sex; but social science speaks of the family — the same organized human activities — as fact and problem. Aristotle said: "The family is the association established by nature for the supply of men's everyday wants,"[5] referring to the living needs of man as met by the organization of the Greek household. The family is the basis of the structure we call society. By that we do not mean that it exists apart from us as individuals or that it is simple and irreducible, but merely that we use the term *family* to refer to very fundamental operations which we perform. What are those operations?

In the first place, the giving of life is one of the chief functions included in the denotation of the word family. The recognition of paternity was undoubtedly a large factor in the formation of the historic family under patriarchial domination, and today reproduction is family business. We are born of a family, excepting those who must carry the bar sinister. Sex life goes on, of course, outside the family, just as drinking goes on in spite of prohibition. And most societies have honored certain selected ones who have had no sex life at all, such as priests, vestals, monks, and nuns. But it is customary to have a sex life and this is, generally speaking, institutionalized as family activity and habitually controlled, excepting in exceptional cases, within that sphere of action. The ultimate significance of sex restrictions, of course, has to do with the bearing of healthy and vigorous children. Even the needlessly cruel treatment of those born out of wedlock, for which condition they are not responsible, appears aimed at no other goal than the dramatic impression of all concerned with the importance of observing group tradition in reproduction. No society has ever permitted one to mate with absolutely anyone of the other sex. Incest taboos are in vogue in even the most rudimentary groupings, and many types of custom may prevail, polygyny, and polyandry, as well as monogamy. The last of these is the accepted family tradition in occidental culture.

Not only is the important function of reproduction a family matter but the early care and training of children falls, naturally enough, within

[5] Aristotle, *Politics,* Bk. I, Ch. 2 (edit. Bekkeri, 1252 b) (Jowett's translation).

the same ambit. Biologically we are what we are because our fathers married our mothers. Socially almost the same can be said, so great is the influence of early training and environment. Parents endow their children with their own hopes and fears, joys and sorrows, virtues and vices. Manners and morals are set within the family rather than without it. "Like father, like son" refers not alone to eye-color and stature. The attitudes and susceptibilities which make up character are set chiefly by that intimate background called the home.

Furthermore, social position and economic status are largely a matter of family. Insofar as professional tradition and training yield social standing, the early home environment provides the child with it. Where friends and acquaintances are involved, the home again provides the locus of early associations of this sort. Moreover, property is transmitted through the family. In all societies the young come into the possession of those objects which have been regarded as peculiar to their specific forebears. The tools of a trade, books of a profession, a house, a farm, stocks and bonds, all are passed, with their attendant advantages, to the young by their parents.

The family is a remarkable balance of functions; all of them important — so important that to have missed any of them is to be crippled in one's living. A man without a family is less fortunate than a man without a country. Within a family group the needs of all are met with astonishing completeness. The husband is interested in protecting and supporting the wife and children. The wife is interested in aiding the husband and in rearing the children. She, the weaker, gains power and security, while he gains provision at home for his daily needs. Parents provide children at birth with racial habits (instincts) and, vicariously, with experience and memory, while children provide for their parents a vicarious immortality.[6]

The changes in the family in recent years have chiefly to do with the position of women. The rise of industry has given women the possibility of financial independence, whether by investments or by their own labor as workers. The World War greatly accelerated the introduction of women into industry. With financial independence has come an increasing restlessness. The home takes up less and less of life; many women continue their work after marriage. The education of women has added to the increased discontent with the older type of home. An educated woman with the capacity of self-support demands a better home or none at all. The immediate result of the various factors at work, of which these are but two, has been to increase divorce and decrease marriage in certain classes of the population. Ultimately, however, after the present bewilderment, a different and better home may result from the improvement in the status of women.

[6] *Cf.* Santayana, George, *Reason in Society*, New York, Scribners, 1905, Ch. 2.

5. Industry

Another institution is made up of our habits of conducting the manufacturing and marketing of commodities. This used to be a function of the family. The early home was a production unit; in it were manufactured all articles consumed, from clothing and candles, to butter, bread, and bullets. The development of modern machinery has caused the family to lose these economic functions, even as it has lost, for the most part, its political functions, and to become more exclusively a matter of personal affection and child culture. As with the family, it is beyond the scope of our present inquiry to do more than suggest a few aspects of this institution. The science which deals with our wealth-getting and wealth-using activities is *economics*.

(*a*) Machinery. — The differentia of modern industry is power-driven machinery. Contemporary civilization is composed of human nature, books, and machinery; and the greatest of these, for purposes of understanding the differences between ancient and modern culture, is machinery. Original human nature has been constant for the last twenty-five or thirty thousand years and libraries developed slowly until the invention of printing. Now books are increasing almost as rapidly as machines. But technical contrivances stand out as the dominant characteristic of our culture.

Machinery is the subjugation of the forces around us to our own uses by means of technical contrivances. It began when the first club was used by some subhuman ancestor of man. It developed through the invention of the lever and of the wheel, which is an extension of the principle of the lever. The wheel, coupled with the solar energy which is found deposited in coal or petroleum, gives us modern industry. The vast piles of machinery which stand in our industrial centers have detailed histories running back beyond the dawn of human records, and roots in nature supporting their multiplex visible growths which feed upon the dank energies of the fossil forests of the Carboniferous age. Man, by his work, has altered the face of nature, but he has also been altered in turn. For these monsters of machinery, like Pygmalion's statue, have produced unpredicted effects. Some of these are worth noting.

Society as a whole, by the use of machinery, has had introduced into its life a great amount of standardization. This uniformity extends from collar buttons to airplanes, from pocket-knives to passenger locomotives. We use similar heating systems, lighting systems, refrigeration systems, and automobiles. We eat food prepared by similar machinery, wear similar clothes made by similar looms and sewing-machines, and we are buried in similar caskets or cremated in similar crematories. The bulk of standardized features in our life has greatly increased through the development of machines.

Furthermore, tremendous amounts of leisure have been created by machines. Whereas the frontiersmen of the seventeenth and eighteenth centuries in America were confronted with manual labor which had to be done as the price of survival, we today have machines to do our bidding and are emancipated from much of the drudgery which was taken for granted by our ancestors. Machines are our slaves. They perform many of the tasks which slaves performed in the ancient world. From this point of view they are the precondition of a high type of culture. Leisure is essential to arts and sciences. Men cannot create great art and science while confronted with a grim battle for bare subsistence. But, given leisure, culture may flower into many a rare blossom. Plato and Aristotle could stroll through beautiful groves conversing on the nature of being and non-being only because slaves did the manual work necessary for life. Today artistic and scientific achievement is a by-product, in large measure, of the gradual liberation of large sections of the population from the menial duties of life. The real " worker " of modern industrial society is not the human being; it is the machine. So efficient is this slave that it has been estimated that, if all of us did our bit, the basic tasks of our life could be performed by merely a four-hour shift per day.

Another aspect of our life which is conditioned by the development of machinery is the change in the nature of wealth. Wealth in the ancient world meant the command, through money, of the commodities necessary for life. Money was sought for its purchasing power. Nowadays money is desired not only for its purchasing ability but chiefly because it means the control of the productive machinery of society. Machinery is wealth and breeds more wealth. Money is sought today for its producing ability. The rich men in modern society are those who own the masses of machinery at the cross-roads of industry.

Certain other specific effects of the introduction of machinery upon those who tend machines are worth mentioning. The handling of intricate machines has increased the intelligence of the manual workers of society. Not only is the notion impressed on them that specific antecedents produce specific effects (the notion of causality), but the changing from machine to machine and the social contacts of the factory, as well as the automobile and the radio at home, have increased the complexity of the worker's life. The manual worker of New Bedford, Fall River, or Lawrence, Massachusetts, is far more intelligent than was Silas Marner.

But most important of all, for the understanding of the contemporary groupings of manual workers, is the fact that machinery has forced upon them the necessity of organization. The essential point is the fact that the worker has been separated from the tools of his trade. In earlier forms of industrial organization the manual worker possessed his tools. The cross-

roads shoemaker bargained directly with the possessors of his raw material and with the consumers of his product. He had equality of bargaining power. But with the introduction of machinery, in the place of the simple tools of earlier industry, the operator of the tools of industry became, more and more, merely a machine-tending animal. The machinery was too vast for him to possess and fell into the hands of an owning class. As a result of this separation of the worker from his tools there emerged, on the one hand, a small aristocracy of wealth, based upon the owning of the productive machines of industry and, on the other, groups of workers skilled in their respective industries but placed in competition with one another for access to the machines. Through the loss of the possession of his tools the worker lost his ability to bargain on equal terms with the other factors in the economic situation. It is within the power of the possessing few to dictate to the dispossessed many the terms of that approach to the machines without which they cannot earn their living.

Given the assumption that business is run exclusively for profit, and given also the uncontrolled possession of the productive machinery by a small class in society, the end is apparent. The competition against himself into which the worker is thereby forced enables those who own the machinery to appropriate for themselves all profit from the industry over and above the amount necessary for bare subsistence. Of course, if wages are forced below the subsistence level, the quality of work deteriorates. It is not maintained that, in any country, the owning class was left in undisputed control. Anti-trust laws, minimum wage laws, insurance laws, child labor laws, and similar enactments were aimed, in fact, at palliating the plight of the producers. Insofar as parties in political power, however, have not worked for the good of the whole citizenry, but for the profit of the wealthy, they have earned that satirical parody of Lincoln's famous phrase, that now we have " government of the people, by the business man, for the capitalist " !

It seems obvious that there is no equality of contract where there is no equality of bargaining power. In order to better his position the worker has organized. Union labor is an effort to eliminate the competition of laborer against laborer and to give the worker something approaching the bargaining power of his position in earlier industrial organizations. Labor organizations in America are essentially defensive in character. The new machines have been used against the worker economically by those who own them and he has retaliated both by his political action, where that has been articulate, and by the direct action of the organized strike.

(*b*) The Control of Industry. — We have said much about the changes which could be made by the introduction, in social affairs, of scientific control. Let us follow up our discussion of economic factors a little

farther and then illustrate what is meant by a " scientific " technique of control in industry.

It used to be thought that economic relations were as fixed as the law of gravitation, that business and industry were to be regarded as spheres in which natural law held sway as it does in astronomy, in which man's control over events is negligible. Economic laws were to be formulated into mathematically accurate form. The law of " supply and demand " was held to be such a formula. " Value " and " price " are a mathematical function

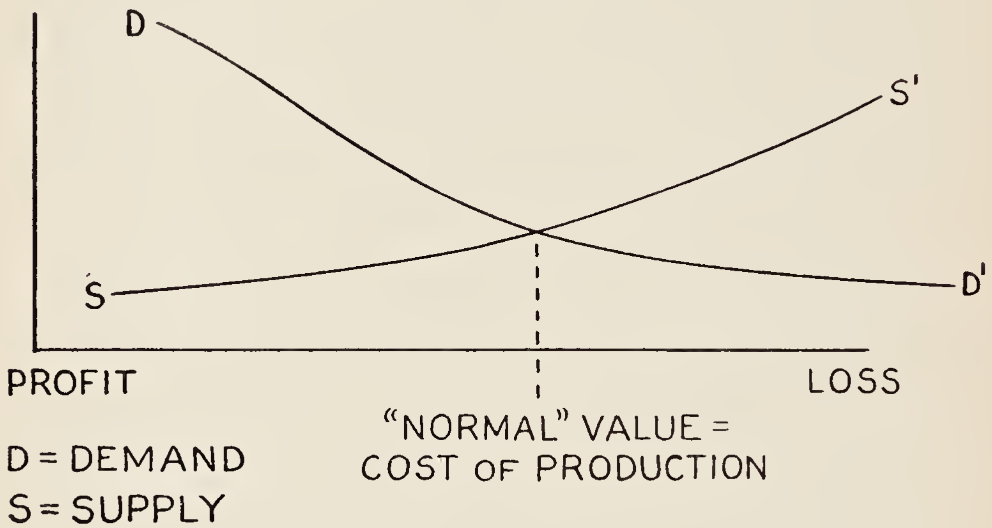

Fig. 14. The Law of Supply and Demand

of " supply " and " demand," the doctrine read. A large supply and a small demand cause a low value; a large demand and a small supply mean high value and prices. Value was thought of, along with the whole unexplored background of industrial life, all production and distribution, as beyond control.

In the history of economics, John Stuart Mill was the first to take the position that economic life was not entirely uncontrollable. Although in his opinion, " the laws and conditions of the *production* of wealth partake of the character of physical truths," to use his own words,[7] " it is not so with the *Distribution* of Wealth." Mill regarded distribution as a " matter of human institution solely." Since the days of Mill economists have come to recognize that production also may be controlled. Both public and private monopolies were evidences which could not be refuted. When prices could be raised by monopolistic control of production, and were so raised in industry after industry, how could one hold to the notion that they were

[7] Mill, J. S., *Political Economy,* Bk. II., Ch. I (published in 1848). Italics mine. *Cf.* Mill, J. S., *Autobiography,* New York, Holt, p. 141.

the result of a " Supply " and " Demand " which were as inevitable as the seasons?

Furthermore, although the so-called " law " of supply and demand might be, in a given situation, a fair enough statement of the operation of those interests called appetites, it was utterly false in respect to other types of interest. For example, one would not give the price of a whole dinner to secure the remaining courses, after the consumption of the main course. True enough. The immediate value of another dinner, when already one is almost supplied is obviously low.[8] But suppose one starts from New York to Chicago on business and the train is derailed at 6 A.M. between Elkhart and South Bend, Indiana. The demand for the remaining few miles is not *less* than it was at the beginning, for any similar number of miles. One might be willing to pay much more for those last miles than for all the rest of the miles previously covered. In other words, there are things which are purchasable, in this case transportation, which are of little value, unless you get the *whole* of what you want. So, apart from manipulation of market and of production, the law of supply and demand was a too great simplification of the facts. It distorted them, indeed, by regarding all interests as of a single standard type when they are, in truth, wide in scope and varied in quality.

Contemporary economists, far from thinking that business and industry are facts to be watched passively as one observes an eclipse of the moon, are well aware that many of the phases of the complex processes of production and distribution are completely and immediately controllable, and that many others are indirectly controllable through long-range anticipation. It is altogether a matter of knowledge. Of course, one will stand in passive awe before a machine of which one is ignorant, even though it be within reach of manipulation. Its processes seem " inevitable." But once one knows the machine one can control it, and the assumption of economic science is that the economic order is an intricate series of processes the bulk of which are readily susceptible to control. The illustration which follows is a part of English economic experience.

The trade board, in England, is essentially a board of control, or government, for an industry. Its composition is effected by the election of representatives by the employees and the employers, equal in number, and

[8] Seager, H. R., *Principles of Economics,* New York, Holt, 1917, pp. 70 f., gives the characteristics of human wants as follows: (a) they are indefinitely numerous; (b) they are of very different degrees of intensity; (c) the utilities of additional units of any good to any consumer diminish normally as his supply of units of that good increases; (d) the utility of future goods is less to the normal consumer than the utility of present goods of like kind and quality by an amount varying directly with the degree of futurity; (e) most wants are determined by social standards of taste rather than by the independent judgments of individual consumers.

by the designation, by the elected members, of a third and smaller group of outsiders to act as representatives of the general public. The third group in a trade board is usually composed of academic men. The presiding officer of the board is elected from among this group.[9] The power of the little neutral group is frequently crucial. Their impartiality, in matters of class interest between the two other groups, is assumed. Upon them is laid, of course, a large burden of responsibility; for the actions of a trade board are binding upon an industry in matters of hours, wages, prices of product, new models, and installation of new machines and processes. The board must put wages at a point high enough to give as tolerable a life as possible to the workers without driving the manufacturer with the largest overhead out of business. It must set prices sufficiently high to allow all the manufacturing enterprises to operate at a reasonable profit and yet low enough to compete with imported products. As the situation changes by installation of new machinery, shift in quality or quantity of demand, or alteration in foreign competition, prices and wages are revised.

The utility of such a device is evident. The wastefulness of uncontrolled competition, involving failure of the less fortunately placed firms, is avoided by deliberate anticipation of consequences *to the industry as a whole* and *to the public.* Instead of sacrificing the interests of the public and of the workers, and of many of the employers, to the possible fortune of a few successful firms in uncontrolled competition, this scheme enables the consumer to get the product at a fair price, insures the manufacturer against cut-throat methods by competitors, and aids in conserving the standard of living of the personnel in the industry. Sudden general epidemics of unemployment can be avoided, if industries use sufficient foresight in making necessary readjustments. The assumption of such a scheme is, of course, that both production and distribution not only can, but should, be controlled.

6. The State

In the habitual political devices of our culture we have another institution. To quote the Stagirite again: " When several families are united, and the *association aims at something more than the supply of daily needs,* then comes into existence the village." [10] Again, when " several villages are united in a single community, perfect and large enough to be nearly or quite self-sufficing, the state comes into existence, *originating in the bare*

[9] The author is indebted to lectures of Professor L. T. Hobhouse, at London University, in the fall of 1920, on the subject " Self-Government in Industry."

[10] Aristotle, *loc. cit.*

needs of life, and *continuing in existence for the sake of a good life."* [11] Aristotle saw clearly that the core of social organization was living activity, and that the meaning of that organization was found in the care exercised over that activity and its consequences.

(*a*) Political Democracy. — The political structures of our own day are almost as troublesome as were the archaic social devices of the early seventeenth century. Democracy is very much criticized at the present time. Spanish and Italian dictatorships, apart from Russian developments, are enough to cause reflection. What is democracy? Is it a preferable form of government? If so, why? If not, why not?

" Democracy " does not mean that the majority *governs.* A minority always has governed, and always will. The exercise of authority involves an ordered focusing of power. But in a democracy the minority which governs must come up periodically before the bar of judgment of all the citizens — all, *i.e.,* who take the immediate consequences of the government's policies. *Democracy, in theory, is systematic institutionalized responsibility in office.* The policies of the ruling class may be ambiguous and the voice of the ruled may be inarticulate. The power of deep and continuous reasoning has been given to few, as we have said, — too few to be a majority, even too few to be a ruling minority, in a modern state. But in the device of representative government, although never representative in any strict sense, there lies the power of ultimate veto upon policy. If things get unbearable, the citizens of a democracy can turn out the public officials and try new ones without bloodshed. It is better to ballot than to bleed. In general, people have the government they deserve. In a democracy at least the possibilities of improvement are there. If these possibilities are not realized, the citizens have themselves to blame.

This does not mean that it is all very simple, for it is, indeed, difficult. No form of social organization is free from inconvenience, for there is a limit to the perfectability of social devices, even when intelligence has done its best. Our territorial basis of representation, the system of electing citizens to represent the interests of various areas, for example, was relatively satisfactory in the days of homogeneous populations — when areas had interests, so to speak. In a frontier society the inhabitants of a given area could trust their elected representative to look after their welfare. It was roughly identical with his own. But in a highly complex society, with multitudinous conflicting interests, a satisfactory technique of representing a large area is difficult of achievement. Some particular interests are certain to be omitted. The banker in New York City has more in common with the banker in San Francisco than he has with the laborer who lives on the East Side, and the San Francisco laborer has more community of

[11] *Ibid.,* italics mine.

interest with his fellow-laborer on " the sidewalks of New York " than with the investing public of his own city. How can senators represent the conflicting interests of opposing economic groupings? The trade board, mentioned above, was devised to adjust some of the economic conflicts precisely because the existing machinery had broken down. And the whole emphasis upon the devolution of authority, the importance of local government, etc., which is now so strongly urged, is evidence that we have been expecting the impossible of the national state.

A trenchant criticism of the existing democratic state has come from English sources which feel the contemporary economic disadvantages of certain classes in English society. The Guild Socialists have worked out a theory of the democratic state which combines the representation of citizens by areas with representation by professions, *i.e.*, functional representation.[12] Guild Socialism involves state ownership and trade-union management of basic industries, and is a typical British compromise between French Syndicalism, on one side, and, on the other, the state socialism of the German variety, which had been the program of the Fabian Socialists in England since Marx. Nationalization of ownership and syndicalism of management is its program, economically considered. The political program of the movement calls for a replacement of the House of Lords by a Guild Congress in which all the producers of the community shall be represented. All Englishmen, as consumers, would be represented in the House of Commons, which would function parallel to the Guild Congress. A joint committee would coördinate the two houses. The plea of the Guildsmen is that this would revivify the decadent democratic state and, by extending self-government into industry, release great energies in the field of production. A diagram of the organization is useful in clearing up this proposed reconstruction of the British Constitution. The adoption of the constitutional devices suggested by the Guildsmen[13] would result in a great increase in the social and political power of the trade unions, particularly of the " Triple Alliance " — the dockers, railroad men, and miners. This is the goal of the theory, and schemes of this sort are in the background of such events as the recent general strike in England. The British standard of living is not up to the level of American life and the incubus of a parasitic owning class is felt since the war much more than it ever has been felt in the United States. Economic pressure forces political issues; Englishmen have to think about public matters. Confronted with a large and active group within the state which aims at a " revolutionary " reconstruction, as conservative citizens regard it, what

[12] Carpenter, Niles, *Guild Socialism*, New York, Appleton, 1922, is a good treatment of the whole movement.

[13] *Cf.* Ward, Paul W., *Sovereignty*, London, Routledge 1928, pp. 114 f.

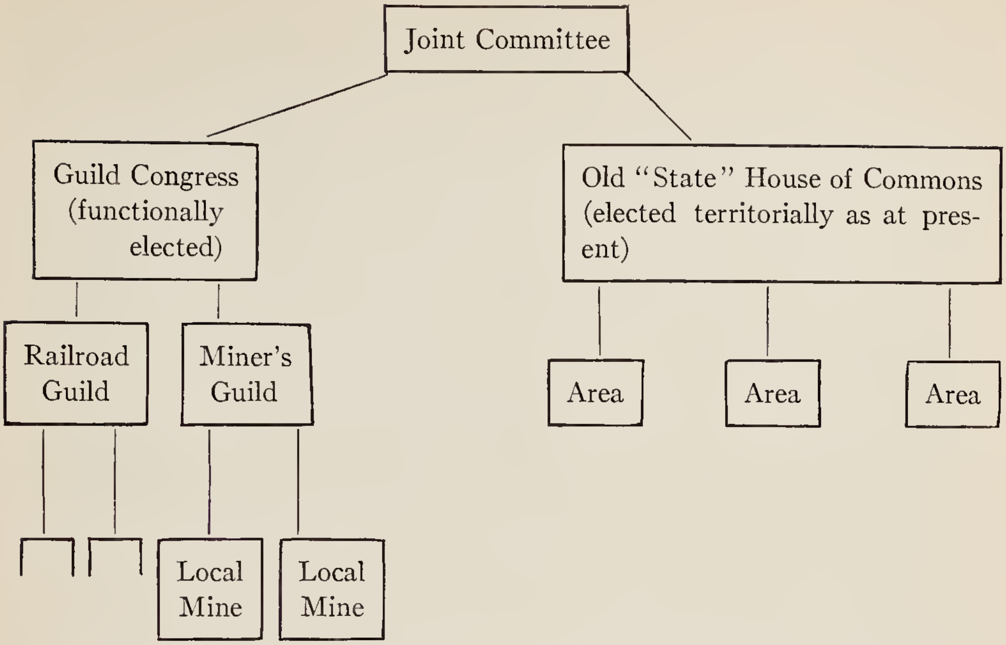

FIG. 15. DIAGRAM OF BRITISH CONSTITUTION AS SUGGESTED BY GUILDSMEN

can the English citizen and statesman do? What can Americans do when confronted with questions of broad import with consequences reaching into decades of future time? Perhaps, because of our superior economic position, we do not feel the pressure of necessity. We can better afford the luxury of blundering. But no intelligent man will contend that riches justify stupidity, however they may in particular places occasion it.

(*b*) SCIENCE AND THE STATE. — Democracy must have knowledge or it will take its place beside feudalism and absolute monarchy as outworn forms of government. For the present, as we live in hope, we may feel, as Campbell-Bannerman once said, that " self-government is better than good government! " Government which is not self-government has demonstrated its futility. But in the long run a certain modicum of goodness is necessary, even in a government. The development of social science and the dissemination of knowledge is crucial for democracy. Even in an ignorant society, as Lincoln said, it is impossible to fool all the people all of the time! If it were impossible to fool any of the people any of the time, good government would be within reach. As Professor Dewey has so well said, " The prime condition of a democratically organized public is a kind of knowledge and insight which does not yet exist."[14]

Social science should aim to remedy this defect and to make possible self-conscious guidance of social reconstructions. A detailed and exact

[14] Dewey, John, *op. cit.*, p. 166.

knowledge is the only alternative to blundering, and blundering in institutional life is fraught with danger. Continual blundering will result in disaster. Some institutions may die peacefully of old age and, like outworn clothes, be quietly discarded; but others possess explosive possibilities. Particularly is this true of political institutions. For it is their business to adjust the frictions between various groups of interests included within a given area. A business concern blunders and goes bankrupt. A fraternal order blunders and disappears. But let a state blunder seriously and it has laid up for itself a fund of animosity which may break out in revolution. The old *régime* in France stored the gunpowder which exploded in 1793. Three hundred years of feudal tyranny by the Romanoffs provided the mass antagonism which resulted in the Russian Revolution. Revolution is the violent internal readjustment of a social order. Revolutions are not produced overnight, but result from a long process of continued strain and pressure among the various activities of the men concerned. Finally, the urge against the existing order becomes intolerable and the explosion results. War is a similar event. A seemingly inconsequential event may trip the stored-up energies and produce a conflict of habits which may prostrate opposing societies. But trivial events do not *cause* social cataclysms. The effective factors are far deeper in character and lie back of the scenery, which may shift with such dramatic and bewildering rapidity in a time of crisis. It is futile to speak of particular men as causing the World War. The war was produced by the whole art of imperialistic statecraft as habitually practised in the nineteenth century. The political structures involved were, and still are, out of date.

In a very genuine sense, the only alternative to scientific social engineering is catastrophe. Aristotle was well aware of the importance of social engineering in the Greek city-state. His analysis of the causes of revolution [15] is a masterpiece of social science and a model to be copied by all political scientists. His doctrine of the middle class is, furthermore, as sound a piece of political wisdom as any extant. He said.[16]

> Now in all states there are three elements; one class is very rich, another very poor, and a third in a mean. It is admitted that moderation and the mean are best, and therefore it will clearly be best to possess the gifts of fortune in moderation; for in that condition of life men are most ready to listen to reason. But he who greatly excels in beauty, strength, birth or wealth, or on the other hand who is very poor, or very weak, or very much disgraced, finds it difficult to follow reason. Of these two the one sort grow into violent and great criminals, the other into rogues and petty rascals. And two sorts of offenses correspond to them, the one committed from violence, the other from roguery. The petty rogues are disin-

[15] Aristotle, *op. cit.*, Bk. V. [16] *Idem*, Bk. IV, Ch. 11 (edit. Bekkeri 1295 b).

> clined to hold office, whether military or civil, and their aversion to these two duties is as great an injury to the state as their tendency to crime. Again, those who have too much of the goods of fortune, strength, wealth, friends, and the like, are neither willing nor able to submit to authority. The evil begins at home: for when they are boys, by reason of the luxury in which they are brought up, they never learn, even at school, the habit of obedience. On the other hand, the very poor, who are in the opposite extreme, are too degraded. So that the one class cannot obey, and can only rule despotically; the other knows not how to command and must be ruled like slaves. Thus arises a city, not of freemen, but of masters and slaves, the one despising, the other envying; and nothing can be more fatal to friendship and good fellowship in states than this. . . . But a city ought to be composed, as far as possible, of equals and similars; and these are generally the middle classes. Wherefore the city which is composed of middle-class citizens is necessarily best governed; they are, as we say, the natural elements of a state. And this is the class of citizens which is most secure in a state, for they do not, like the poor, covet their neighbor's goods: nor do others covet theirs, as the poor covet the goods of the rich; and as they neither plot against others nor are themselves plotted against, they pass through life safely. . . . Thus it is manifest that the best political community is formed by citizens of the middle class, and that those states are likely to be well administered in which the middle class is large, and larger if possible than both the other classes, or at any rate than either singly; for the addition of the middle class turns the scale, and prevents either of the extremes from being dominant.

According to Aristotle, a wise legislator will always include the middle class in his government. The rich and the poor will never consent to be ruled by each other, because of their mutual distrust. The arbiter is the middle class which stands between the two extremes. " Clearly, then, the legislator ought not only to aim at the equalization of properties, but at moderation in their amount," he says.[17] By conserving his middle class, he makes a stable society. But it is not merely a matter of property. " It is not the possessions but the desires of mankind which require to be equalized and this is impossible, unless a sufficient education is provided by the state."

This is sound doctrine when applied to the modern state. The stability of a social order is directly proportional to the amount of economic and social equality present in it. It is the dispossessed who work up revolutions. The meaning of taxation is, in general, not to be found in the necessity for funds to pay public officials. The state could be supported by a tax on salt if necessary. The ulterior meaning of a taxation program — income taxes, inheritance taxes, property taxes in general — is the effect such a program

[17] *Idem,* Bk. II, Ch. 7 (edit. Bekkeri 1266 b).

has on the ultimate distribution of property. Every shift in taxation takes money out of one pocket and puts it into another. In each situation the question should be, what is the effect of this revision upon the distribution of property?

(*c*) Internationalism. — One of the chief problems of political scientists today is to develop political techniques to inhibit war. The modern state arose when high feudal officials shook themselves free of the restraining power of Pope and Emperor and reduced their immediate subordinates to relative impotence. They became kings of national states. They did this by fraud and violence when it could not be done by peaceful means. They applied to themselves all the high-sounding words which the Roman Emperor, the Holy Roman Emperor, and the Pope had used of themselves, claiming *sovereignty* — supreme absolute power, superior to the laws, inalienable and indivisible. There is no disorder so long as one person has supreme absolute power; but let several people claim it, and try to exercise it, and the result is war. So the sovereigns of modern monarchies got into various troubles with each other, the evil consequences of which were borne chiefly by their unsuspecting subjects in the name of patriotism. And when the monarch was made a mere figurehead, or dispensed with altogether, as responsibility was emphasized and democratic political forms developed, the sovereign national state emerged claiming all the irresponsible prerogatives of its two-fisted and bellicose predecessors. The result has been war, and more war; and because middle-class governments are in power, and industrialism has produced a high degree of efficiency in production, the intensity of the conflicts has increased progressively. Instead of feudal aristocrats going out in tin suits to spar for a few hours and receive an occasional wound, war means today that whole nations engage in a deadly grapple. War is no longer a sport; it has become a business.

Formerly nationality was an ideal interest, a wider and more liberal goal than sectional interests. Throughout most of the nineteenth century nationalism was this, in the Greek and Belgium revolutions, as well as in the American Civil War. Furthermore, the national state was there as an instrument of execution, and power gravitated into its hands. It seemed to represent to the citizen the conservation of all the historic values of his civilization, race, language, religion, literature, as well as furnishing him with a technique for getting things done. Small wonder that men came to worship the nation-state with a fanaticism reminiscent of the religious wars of three centuries ago. "My country right or wrong," that slogan of the flamboyant patriot, could be smiled at as merely silly today, were not the attitude which it expresses so dangerous and so reprehensible morally. For nationalism, carried over into the twentieth century in all its

nineteenth century vigor, has become both a menace and a nuisance. That we should hate, fear, despise, and kill each other because, forsooth, part of us are Germans and part of us French is not only futile but utterly inane.

There are two ways of looking at the fact of nationality in political affairs. We may say: (1) All cultural nationalities (based on race, religion, language, etc.) must have independent political structures; or (2) There is no necessary connection between administrative political structures and nationality. After the World War the Paris Conference split up Central Europe in terms of the first principle, and organized the League of Nations in terms of the second. In this settlement there was a certain just appreciation of the importance and utility of national groupings, coupled with a recognition that they must be held in check by some more impersonal structure. The League of Nations as a means of encouraging *toleration of nationality* may become very useful indeed. The religious wars of days gone by disappeared with the adoption of a policy of religious toleration; political structures became non-religious. Peace resulted. Political structures may become non-national as well. There is no German State in Wisconsin and no Scandinavian State in Minnesota; and the League of Nations is neither German nor French, Polish nor Russian. The League has the double advantage, therefore, of not only (1) providing an instrument of adjustment already there and available for use in international disputes, but also (2) of lifting those disputes out of the fogs of particular national animosities. The unventilated fervors of a patriot are not the stuff of which real statesmanship is made.

The question of international adjustment is one of the great social problems of the day. Politically the chief international problem is, What about war? Whereas the chief domestic problem is, What about finance, taxation, and the distribution of property?

(*d*) Law. — Legal institutions, both within and without the state, are important and instructive. Some social problems, such as that of internationalism, can be approached fruitfully as questions of making enactments legally effective and enforceable.

Law is the body of stated rules which must be obeyed within a given area. In earlier days, it was primarily an expression, in verbal form, of the habits of the community. Of course, when the group customs lay below the level of violation — too deep for question, so to speak — they were not formulated in words. Activities simply happened that way. But when breaches of custom occurred, reflective formulations became necessary. The community felt called upon to defend its customs. Law in the sense of *common law* is, therefore, a statement of the way in which things have been habitually done, with the added implication that they are to be done

that way in the future. Common law grew as decisions and precedents accumulated; it became a tradition. *Legislation,* as an explicit function of political structures, arises late in history. It is an effort to lay down, antecedently, the conditions of human action. The end of all law is to safeguard certain activities and to circumscribe, or eliminate, others. Its reference is always to the future, and its consequences in operation are its ultimate test.

The rules which must be obeyed in a society are *enforced* by *penalties.* However much earlier and ruder societies may have been animated by vindictiveness and a spirit of " squaring the account " in the imposition of penalties, modern society acts in no spirit of vengeance in enforcing its rules. A penalty is exacted neither for vengeance nor for the reformation of the criminal; but *punishment is inflicted to prevent the particular kind of activity from occurring again.* Forgery is penalized by a penitentiary sentence; the aim of the penalty is to prevent *all forgeries* in the future. If the individual forger is reformed, so much the better. But if the desire on the part of the community to prevent the particular type of action is very great, it may outweigh entirely the regard for the future conduct of the individual culprit, and the death penalty may be inflicted. Many states use capital punishment in cases of murder, a crime difficult to prove, and one which may be animated by a wide variety of motives. It has never been scientifically demonstrated that death is a greater deterrent to crime than life imprisonment. If it should turn out to be so, death would be used as a penalty for those actions which the particular society absolutely refused to tolerate.

Jurisprudence has been studied as carefully and continuously, in modern times, as any other social science. Since the days of the Italian universities of the Renaissance, law has been an object of attention. Nor has emphasis upon method been lacking. Procedure is important in legal affairs; many a good case has been lost through defective legal process. But contrast the method of law with that of physics, and the differences are instructive. The physicist works out his problems in a laboratory with instruments of precision and in the peace and quiet without which genuine intellectual work is impossible. Legal decisions are rendered, frequently, in an entirely different atmosphere. A murder case may well resemble a prize fight, or a three-ring circus, rather than a scientific experiment. No one can deny that scientific method would aid legal science. Nor can one say that legal decisions make little difference, anyway. Law is important in social engineering, and matters of enormous social significance are decided by judges. This very importance of law makes it imperative that legal procedure be made self-consciously scientific.

The " law of nations," the international law of former days, developed

as a body of habits in international affairs. It was a growth similar in character to the common law. Precedent and custom were its guiding principles. Formulations of these were occasionally ceremoniously agreed to by various combinations of powers and just as frequently unceremoniously violated when the occasion demanded it. The League of Nations today, a body with stated meeting times and a geographical center, formally designated, represents a tangible, though experimental, effort to develop the function of legislation in international relations, *i.e.*, the anticipatory laying down of rules, and the deliberative framing of policies jointly to be pursued.

7. Is There Social Progress?

If we define an institution as a body of activities, the question arises as to the direction of movement. Is there such a thing as " social progress " ? What precise meaning is attachable to the phrase?

Men tend to be optimistic about themselves and to think of a total social progress which moves on toward some " far off divine event " inevitably to be realized. The *Civitas Dei* of Augustine, the Utopias of various writers, are imaginative sketches of goals once thought of as really attainable. Furthermore, the philosophers of history, Hegel, Cousin, Comte, Marx, Spencer, have had their notions of a general ascertainable direction of the total bulk of human development. Some have been based on false biology, as Spencer's belief in the inheritance of acquired characteristics. All have been based on false psychology.

Biologically we have not progressed since the dawn of civilization. Biological generalizations give no support to social optimism. Indeed, Galton could say that the ancient Greeks were as much above the Englishmen of his day in native ability as those same Englishmen were superior to the Hottentots of Africa. And the social philosophers of history, *e.g.*, Hegel and Marx, predicted subsequent stages of history which did not result. Nor is it obvious that there has been any increase in the sum total of human happiness, in spite of the prevalence of the notion.[18] The World War was the most organized, intense, and wide-spread misery the world has ever seen.

The movements of social institutions, of men's organized habits, are better thought of as *changes in specific directions*. Total changes are impossible, for change can be noticed only on the background of that which does not change. Above the fixity of our biological natures, and of our basic habits, we can think of the moving institutions of society as changing, here and there, bit by bit, in some cases growing, as cells proliferate, in

[18] *Cf.* Ward, Lester F., *Dynamic Sociology*, New York, Appleton, 1898, Vol. II, pp. 173 f.

others moving rapidly, like avalanches down a mountain side. *There is no progress in general, but there are specific progressions.* It is easy in social affairs to commit the fallacy of abstraction. We commit that fallacy when we regard the universal " progress " as existentially real, rather than as our notion of the generic features of specific progressions.

Specific strands of our civilization undergo intensive development, as we have seen. There are various ups and downs. The appearance of something new here means the alteration or disappearance of something old there. For example, the ascendance of constitutionalism meant the decadence of absolute monarchy. Today the growth of dictatorship means the decay of democracy in the countries concerned. In general the progressions which have characterized the modern world have been technical. Mechanical processes have developed enormously and the machines which we discussed above are the monuments of modern civilization. But many other detailed developments may be traced besides the technical progressions which make this the " machine age."

The development of constitutional government, which we have just mentioned, is an interesting example of the slow growth of a political institution.[19] In the modern period it was England's contribution to the evolution of the nation-state. England was the " mother of parliaments." The original Parliament was a high court, composed of nobles, which the absolute monarch called in to help him pronounce upon difficult cases. This court did not pretend, at first, to *make* law. It merely stated what the law was (as the jury did originally for common law) in reference to specific cases which the King succeeded in bringing under his jurisdiction. A conflict gradually emerged between the common law of England, as interpreted by the various judges, and this high court of the King which insisted upon stating what the law was, irrespective of the common law. In the early 1600's the quarrel between James I and Charles I and the common-law lawyers, as represented by Sir Edward Coke, Chief Justice, was hotly waged. Who was to say what the rules were which had to be obeyed — the justices interpreting the common law or the King as advised by Parliament? Some men took the part of the King.[20] And then, under Charles, there came the Long Parliament. As a result of the long session of Parliament and the subsequent familiar shift of scenery — the execution of Charles, the ascendancy of Cromwell, the Restoration — with the " peaceful revolution of 1688 " William and Mary came to rule

[19] *Cf.* McIlwain, Chas. H., *The High Court of Parliament,* Yale University Press, 1910, last chapter.

[20] *Cf.* Dewey, John, " The Motivation of Hobbes' Political Philosophy," in *Studies in the History of Ideas,* New York, Columbia University Press, 1918, Vol. I, pp. 88 f.

England *by act of Parliament.* The "high court," in other words, called in by an absolute monarch to give added authority to his will, took the lead in the development and emerged at the end of the seventeenth century in possession of the supreme power. It enacted statutes which common-law lawyers had to enforce, whether they wished to or not, and it determined the succession to the Crown irrespective of the wishes of the royal family. In this way representative government was invented, and modern democracies of the eighteenth and nineteenth centuries simply dropped out the monarch and extended the suffrage.

In the same manner progression after progression — political, economic, religious, educational, legal — could be traced historically, as each issues in some contemporary form, or institution, which can be analyzed in cross-section and comparatively studied. To pass from the sublime to the ridiculous, the bulldog first appears in history around the beginning of the fourteenth century. He was used in England to bait bulls, and was bred for a short nose, heavy structure, and an enduring bite. The breeding of bulldogs is as much an English institution as Parliament. Furthermore, it has developed. But withal, as Parliament and the London kennel clubs emerged, there disappeared the absolute monarch, who first called the "high court of Parliament," and the bull-baiting from which the bulldog draws his name and once drew his *raison d'être.*

It becomes apparent that social science has its prime utility in making evident the consequences of public policy. Adequate knowledge would make possible the steady growth of a social order without violent and wasteful conflicts. Apart from enlightened statesmanship, the ups and downs of social institutions are merely series after series of accidental catastrophies, spaced by periods of prostration and recuperation. We are now in a period of reconstruction after the greatest social catastrophe of all history. The old order blundered; indeed, it *was* a blunder! And humanity has not yet paid the full price of that tragic ignorance.

8. Education as Social Engineering

That social science comes to its focus in education was well known to the ancients. Aristotle not only indicates the importance of public education but states explicitly that the factor which most contributes to the permanence of constitutions is the adaptation of education to the form of government.[21] The best of laws, he says, are of no avail unless the young are trained and habituated in accordance with the constitution.

Education is the remaking by society, in each generation, of the pattern of its conjoint activities — its institutions. The home, the school, the

[21] Aristotle, *op. cit.,* Bk. V, Ch. 9 (edit. Bekkeri 1310 a).

church, the state, — all are continually in the remaking. One cannot avoid the conclusion that social improvement is conditioned more by changes in education than by alteration of any other social technique or of machinery. Education takes the raw material of human nature and imparts habit and develops intelligence. The way in which this is done, in the mass, sets the character of the succeeding age.

Unfortunately there is a lingering superstition that if one knows something one can teach it, and, consequently, little attention has been paid to the methods of deliberate instruction. Particularly is this true in higher education. Elementary schools have been attended to more than any others. Secondary schools have their methods fairly well worked out. Colleges and universities are the poorest of all educational institutions in their methods of instruction. The university teacher has frequently paid little, if any, attention to the methods of his teaching. As a matter of simple social engineering, contemporary education as a whole is about as far advanced as was the practice of surgery before the days of Lister.

Education is of special significance in a democracy, and the democratization of educational techniques is one of the problems of American society. The educational traditions of this country have been essentially aristocratic and they lag behind the structures which they might well be altering for the better. Desired changes in the social temper and outlook can be easily and peacefully effected by introducing them in the schools. A rather complete shifting of social institutions, were it sought, could be effected painlessly, in one generation, by proper educational control. However, be it noted, in a modern democratic society education cannot be thought of as a means of imposing upon the young a preconceived social structure, not even the existing one. A certain conformity to educational devices is essential, of course, to the assimilation by the young of the positive fruits of their legitimate social heritage. But democratic education aims at enlightenment rather than docility, at freedom rather than subjection. The French minister of education who boasted that at a certain hour all the children of France were studying a certain prescribed lesson would be an anomaly in our contemporay educational system. We cannot educate too specifically for a world we shall never see. An intelligent flexibility is the best endowment to hand on to posterity. To teach men how to teach themselves is the goal of education in a democratic community — to free the energies of human nature to their fullest possible utilization, not with reference to a norm to which they must be fitted, but in anticipation of a widespread utility about which we can only guess. Men will prize in the future, as they have in the past, " the fighter's daring, the wise man's understanding of his duty, and the good man's self-discipline in its per-

formance." [22] Education will have served its purpose if it fits the oncoming generation to do well the things which will come to hand in the progressive increase of the various goods and services of life. Where specific training is possible, it must be thorough. Where enlightenment is the goal, it must be vivid. Where risks are to be run, they must be faced intelligently. For it is true today, as in the days of the immortal Pericles, that "the secret of happiness is liberty, and the secret of liberty is courage." [23]

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PART II

LOGIC: A PHILOSOPHY OF SCIENCE

CHAPTER VIII

THINKING

The chapters of Part One have presented in brief compass some of the scientific notions of our contemporary civilization. The methods, or techniques of procedure, employed in the various fields of knowledge have been indicated with varying degrees of explicitness. It is our purpose in Part Two to present a concise critical account of those methods of thought which in operation have produced our remarkable contemporary scientific heritage.

1. The Study of Scientific Method or Logic

The aim of a critical account of thinking is twofold. Its primary purpose is to describe carefully the conditions and to state the nature of the process called intelligence. Its ulterior goal is the improvement of thinking. Wherever it is possible these two purposes go hand in hand in the scientific treatment of any subject-matter; the distinction between them is roughly indicated by the familiar terms "theoretical science" and "applied science." Theoretically, we demand a notion, or idea, of what thought is. This theoretical study passes into the applied phase of the science when the idea is used as a standard. The notion of what a thing properly *is* becomes, in use, the standard of what it *ought to be.*

In general, knowledge, or science, promotes production, or art. To know is to know *how.* The science of thinking is peculiar, however, in that its application results in more science. Its aim is to know how to know. A reflective account of thought, called *logic,* makes for the improvement of science itself and, thereby, the improvement of all production, or art. Any genuine improvement in technique which is made available to all scientific workers results in an increase in scientific productivity all along the line. Ages which have made distinct advances in methods of thought are called, historically, periods of enlightenment. The central position in culture of reflective knowledge is readily apparent. The civilization of an age is no better than its methods of thinking; indeed, its civilization is its scientific procedure in application. A generalized account of the scientific method of a cultural epoch is both a statement and a criticism of its civilization.

As we have seen, specific scientific disciplines deal with particular groups of subject-matter. Physics, chemistry, biology, and the other concrete sciences are concerned with specific and differing events, or with radically different aspects of the same events. Many objects may be approached by numerous routes; the world is so complex that man goes at it piecemeal. A human body, for example, may be regarded as a mass in motion; the science of physics would describe the fall of a man from a scaffolding to the street in the same terms which it uses in reference to the fall of celestial bodies. The identical human body, however, might be made the subject of chemical analysis; furthermore, biologically considered, it has structures and functions which are classified as *Homo sapiens*. Psychologically, the same human body possesses the activities which mark it as an intelligent being; the psychologist may discuss its habits, sensations, reflexes, desires, memories, or reflections. Sociologically, it may be treated as a member of a family, a church, a fraternal order, a trade union, a country club, or as a citizen of a state. All these various approaches are methods of getting hold of the subject-matter. Thought utilizes any distinction which may serve its purpose and, where it is clear-eyed, abandons distinctions which are fruitless. But throughout all the apparent diversity of techniques there may be discerned a unity both of purpose and of procedure. It is the business of Part Two to distinguish these similarities and to define these generic techniques of science.

2. Some Aspects of Science

Science is always abstract. It attends to selected portions of the world. As civilization has developed, the aspects of the world which have been selected for consideration have become more and more minute and exact. At the same time they have become more abstract; they are less like the original world of unreflective experience. In ancient science stones fell because of "gravity"; fire rose because of "levity." Modern physics speaks of four-dimensional space, protons and electrons, fugacity, and a host of other minutiae which are totally unrecognizable to the uninitiated. Activities which are very minute have become objects of acute attention. Elements formerly regarded as incidental and accidental, or totally lacking in observation or conception, now are regarded as basic in importance. This abstractness of science is frequently a difficulty for the beginner. The language of all science must be learned, as one learns the number series, or the properties of Euclidean space. To think about thought should be, indeed, no more difficult than to think about the quantities of algebra or the properties of right-angled triangles. Such objects also are abstractions; they, too, are selected portions of our experience which are dealt with separately.

Another aspect of science is its simplicity. There is nothing occult about science. It is merely the most useful way of confronting the world in which living goes on. This is not meant to imply that confusions of thought do not take place, or that the content of science may not be intricate. Mistakes are real, and experience is delicately involved. The formulas which deal with it are multiplex. But the essence of knowledge, the *thinking correctly* which is the core of the matter, is simplicity itself. If the method of thought be correct, the formulas which result will be adequate. Thought will have served its purpose. Once the general character of scientific method is grasped, the special sciences and disciplines which make up human culture are seen to fall into their respective places as specific attempts to employ that method. The culture which may first appear to be an overpowering confusion of details is, in brief, the composite result of repeated and scattering attempts to apply to the world a procedure which is both unified and easily understood. As a preliminary step to enlightenment, therefore, it is indispensable to gain some notion of what this method is. The beginning of wisdom is a knowledge of method; and it is also the end of it. To have mastered the method is to be wise. The man unversed in scientific ways of proceeding, whatever else he may be, is a blunderer.

This may seem like a fairy tale. That the dragon of Ignorance may be slain in his lair by the invincible sword of Method sounds a bit too idyllic. But there is no fairy tale more strange than the history of man. Scientific progress has been achieved again and again by the simple process of importing a more effective method into a field hitherto dominated by archaic procedures. Modern physics was begun by abandoning the traditional grammatical physics of Aristotle in favor of empirical observations mathematically recorded and interpreted. The mathematics which the Greeks cultivated *in vacuo*, so to speak, separated from the rest of experience, has been progressively developed and applied throughout many other fields of knowledge since the seventeenth century. And the process is continuing. There are phases of experience to which mathematics cannot be applied fruitfully, but the success in physics was so startling as to invite the attempt to apply it universally. Today, mathematics and its offspring, statistics, are like the proverbial poor — with us always. This is but a single instance which may be multiplied indefinitely. Pasteur's shifting from chemical to biological procedure in treating fermentations is an illustration of the same thing on a smaller scale. Our control of microörganic life has resulted.

The importation of methods from neighboring fields, whether new or merely untried, is not always happy, of course. Astrology was the attempt to apply astronomical methods to social events; the results were *nil*. Herbert Spencer's little formula for social progress, his notion of the progressive transition from relative homogeneity to heterogeneity, was taken from the

rapidly developing science of embryology. Spencer tried to clap the formula onto the universe, and failed in the attempt. The fact is, however, that the methods of the most rapidly developing scientific field in any age tend to be borrowed by other workers in neighboring fields.

Today the influence of biology is very marked. The great advances of that science in the last half of the nineteenth century caught the imagination of scientific men, and psychologists, sociologists, chemists, and physicists are all striving to assimilate the meaning of the biological methods associated with the doctrine of evolution. The fields adjacent to biology have become thoroughly developmental in character, including all the so-called social sciences. Any genuine progress in scientific method obviously means an advancement of culture, and a mastery of the approved procedure, at any cultural level, affords an enlightenment which can be achieved by no other means. Part Two aims at continuing the introduction into contemporary science and civilization by initiating the reader reflectively into the mysteries of the scientific method which distinguishes our culture from that of all previous ages.

3. The Improvement of Thinking

The improvement of thinking has been mentioned as an aim. The importance of this can scarcely be overestimated. The increasing complexity of our environment calls for more and more careful control of both thinking and ourselves if violence is to be avoided. Civilization is a race between knowledge and disaster. Man must not only know how to produce new contrivances which enlarge his power, but he must know how to use them. And this knowledge must not be esoteric, the exclusive possession of a favored or gifted few. Depth and range of thought are demanded today of every human individual. For example, the political systems of democratic countries imply an intelligent and discriminating citizen, who knows what he wants and how to get it. Frequently he knows neither, and matters of great social importance are badly managed as a result. If the voter is stupid, democracy fails as a system. Even if a wide-spread native ability be granted, it is evident that democracy implies the education of the whole population. And this training in thinking must be carried on continuously. For nature has been niggardly to man in that all the excellences of his nature must be reproduced each generation. Character and intelligence must be constantly reachieved. Man no sooner learns how to live than he is at the point of death. The living must then be done by others who have not yet learned how. The problem of improving thought is thus seen to be doubly difficult. A vast amount of education is demanded that we may think even as well as we have in the past. The raising of the general level

of intelligence may well appear impossible. Yet if our life is to improve we must think better and better. Advancements in the natural sciences and in society, in matters of conduct and politics, await the systematic application to human affairs of more effective methods of procedure.

4. Preliminary Analysis of a Typical Instance of Thinking

Psychological analysis has made it clear that, in general, thought takes place in situations which are problematic in character, when habits and accustomed behavior have failed to carry on. A boy out walking in the afternoon suddenly comes to a stream too wide to jump. It poses a problem. Immediately the necessity of defining the exact nature of the difficulty is felt; he looks up and down the stream in search of a narrow place, a bridge, or some other means of crossing. As he analyzes the situation a possible solution is suggested; there is a row of telegraph poles visible at the top of a short rise, running at right angles to the stream. Remembering that telegraph poles usually are found along roads, the boy infers that there is a road crossing the stream. The suggestion is elaborated; if there is a road and a bridge, he can cross safely and dryly. If not, he'll be no worse off up there than he is now. So he starts toward the row of poles in the hope of getting across a bridge; he is acting upon his theory or hypothesis. If he comes upon a road and a bridge, he crosses; his hypothesis has been a true one. Thought has come to his help, and his act of thought is terminated by his crossing.

Take a more elaborate situation. A young man or young woman is confronted with the problem of earning a living. The death of a parent, growth to adult age, financial reverses, or any one of a number of other factors, may cause the young person to become aware of the problem and accurately to define it. The finding of a solution is frequently not easy. Trades and professions present themselves as possibilities, and the intelligent youth considers carefully the genuine opportunities which confront him. An *imaginative rehearsal of consequences* takes place. This can be diagrammed as follows:

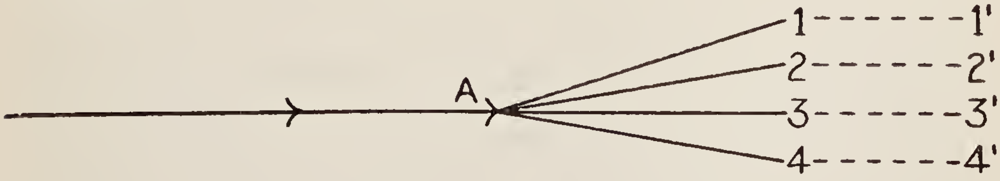

Fig. 16. Diagram of an Act of Thought

At A the problem is thrust upon him; he imaginatively envisages the possibilities, 1, 2, 3, 4, perhaps medicine, theology, the shoe business, and pharmacy. He anticipates what 1′, 2′, 3′, 4′ will be: "if I go this way,

I will come out as Mr. X over there, who has spent his life at it. Do I want to do that? " Successively he *tries on in imagination* one career after another, as one might try on hats until the right one is reached. Finally, one career is envisaged in such a way as to call out the youth's approval, and he undertakes it. Perhaps he has been fortunate enough, or wise enough, to make a good choice; perhaps not. If not, he must subsequently go through the process of selection again, with more restricted possibilities, until at least a tolerable solution is reached. Misinformation or ignorance may cost years of useless effort in the solution of such a problem, or may produce an unfortunate misfit.

An act of thought has, therefore, several distinguishable steps in it: (1) a problem is confronted, (2) the difficulty is defined, (3) a solution is suggested, (4) that suggestion is elaborated by reasoning out its possible results, and (5) the suggestion is tried out in action and is accepted or rejected.[1] These steps, of course, may overlap. The correct solution in some cases may indeed come so quickly as to seem to be the result of a single step.

Such a general outline of a particular act of thought is useful to the beginner by way of determining the locus of his attention. Concrete intelligent acts are the objects of his investigation. But some notion of the relation of intelligence to other distinguishable living activities, and to the world, is also valuable. To write of this in detail is to create a philosophy. However, our purpose here is not to construct a philosophy, but merely to bring out certain distinctions and definitions which are important. The fact that thought occurs in *problematic* situations indicates its place in the economy of man's nature. So long as human activity is unfolding easily and successfully we do not need to think. Thinking comes in when the instinctive or habitual actions are not enough, when these activities crowd and impede each other, as has been pointed out in Chapter Five. Thinking is a kind of adjustment, a learning of the lessons of life, but a learning on a different level from other types.

5. Levels of Learning

Even the humble amoeba and the lowly paramoecium learn. But they do it by that fumbling process which we call *trial-and-error*. This is simply the gradual conditioning by the environment of the random movements made by the animal until a more adequate response is achieved. Trial-and-error is characteristic of vital activity at every level. The hungry cat learns to get out of the maze, and the scientist learns the meaning of a new experimental effect by groping along in this wasteful way. There is no

[1] *Cf.* Dewey, John, *How We Think*, New York, Heath, 1910, p. 72.

other way to deal with a totally novel event. Where one can get no leverage, all one can do is fumble. Moreover, at the lower levels of life there is no technique of transmitting the lessons learned by one generation to its successors. Every paramoecium begins, therefore, at the beginning and must fumble its way along to the end, unable either to learn from its elders or to teach its offspring. The biological advantage of being able to learn by indirection, *i.e.*, learn from others what they have found out, rather than by direct and often painful experience, needs only to be pointed out to be appreciated. When animals learn from each other, as well as by trial-and-error, then a *culture* has begun. There has appeared a transmissible pattern of activities.

This brings us to the next level of learning, that of *imitation.* Dogs, cats, chimpanzees, indeed almost all animals, learn by this method. They see what is done by others and then try to do the same thing themselves. If only a small part of an action can be so learned, the amount of trial and error necessary is greatly reduced. The ability of some animals to imitate the actions of others is so great that only a little fitting at the ends, so to speak, is necessary. The whole pattern is taken over *in toto* and, upon repetition, becomes a part of the habits of the initiate. One type of learning merges into the other gradually, however, as in the human being, who begins as a baby with merely trial-and-error, but adds more and more to his "tricks" by imitation, until the imitative aspect of his conduct becomes dominant. Language is learned, of course, by imitation. Children fumble with their speech mechanisms, but without others would not learn to speak English, or any other particular language. The presence of others is the condition of the transmission of all aspects of our culture or civilization. We learn by imitation. We can therefore take advantage of others' mistakes; and education appears as a systematic transmission to the young of the previously learned lessons of experience. A great amount of education is necessarily a matter of imitation and of memory.

In thinking there emerges a new level of response, presupposing the other two types of learning, but differing from them. Mere overt fumbling would leave life at the level of the lower organisms. It is too disorderly. Mere imitation, on the other hand, is too wooden and mechanical. Life fumbles and learns; other life may imitate the learned activity. But suppose the situation is only partially like the one in which the previous imitation took place? A merely imitative animal would try to carry out the learned response nevertheless and, when at a loss, resort to overt fumbling. But with man a finer type of adjustment takes place, for man is a *thinking* animal.

When brought to a halt by a novel and compelling event, man may not merely fumble overtly or imitate mechanically what he once saw some-

one else do. He may reflect. In reflection there takes place an introversive activity. He *stops* and thinks. Instead of having the action selected merely by random overt trial-and-error, or arbitrary habit, an *internal* selective process goes on, as in our illustration of the young man or woman selecting a career. Overtly nothing is done for the time being; thinking is a kind of respite activity. But an internal fumbling goes on. The activity which might have been habitual, or imitative, or instinctive, is broken up by reflection into bits and fitted together in imagination. It is tried out in anticipation. All the other types of organic processes must be there in problem-solving in great profusion, but there is this additional "fitting" antecedent to the actual wearing of the proposed new suit of action. The great complexity and native looseness of man's activities makes possible this flexible type of adjustment. The other and lower types of activity are not given up; indeed, they are there in greater degree. Adult man has more imitativeness and a larger number of habitual organizations than any other creature. It is that very fact which makes a new and internal type of adjustment necessary. Man's possibilities of reaction are so rich and numerous that his actions would fall over each other, so to speak, unless they were ordered and held in check by each other.

6. The Building of Ideas

Man notes the similarity between one event and previous events, and there naturally follows the inference that one event means what its similar predecessor meant. Consequently, man tries to behave in the ways which have previously turned out successfully and to avoid ways which have previously been disastrous. He applies his previous experience as a kind of map by which he proceeds in the present difficulty. The most significant thing about the function of thinking is that something is anticipated; *thinking is systematic anticipation.* A *concept* is a symbol for a class of objects. It is a mental formula representing the assertions to be made regarding the traits to be met with in the objects concerned. This anticipatory aspect of thought gives it its great value as the most important of man's ways of acting. The fact that previous acts leave a deposit or residuum, in terms of which more and more successful anticipations are possible, enables man to adjust himself to his environment more readily than does any other animal. Man anticipates the environment before it arrives and can make preliminary adjustments to heighten the possibility of success or to soften the blow of inevitable disaster. This ability has tremendous survival value, and, as it developed, puny man conquered animals much larger than himself and preserved his life in the face of many a hostile environment. Man carries the past along with him, and rediscovers

it in the future. When he does this artfully and successfully, his knowledge has become exact. *Scientific thinking is systematic, controlled description and anticipation.*

Aristotle regarded thought as a living function which presupposed certain antecedent functions, or types of soul (ψυχή). The most primitive type of soul is the vegetable soul,[2] composed merely of the two functions of growth and reproduction. Above this and presupposing it comes the animal soul, composed of the five senses and locomotion, in addition to growth and reproduction. The rational soul, possessed by men and beings like men, or superior to them, develops out of the animal soul. All animals have the critical faculty of sense perception,[3] *i.e.*, the five senses. Some animals retain their perceptions. Those who do this have memory. But memory is not thought. Many perceptions, retained in memory, concrete, or fuse, into a single unity in experience, and the notion, or idea, is the result. We might say that some one retained sense perception becomes utilized as representative of all other similar perceptions and assumes thereby a logical universality. The particular object is then seen as a particular. Aristotle illustrates the forming of the universal, or notion, by the figure of a retreating army. First one soldier halts, and then another, and finally the whole force is assembled. In like manner, perceptions halt in memory and, by their amalgamation in experience, a universal idea arises. These notions, or ideas, are the first principles of both art and science. Thought (νοῦς) is, therefore, the crowning function of human nature, presupposing all other functions as its living conditions, and involving a realization of activities utterly impossible to lesser creatures. But not only does reason appear psychologically as an activity, so to speak, an immaterial pure activity vibrating back and forth, building up series upon series, to be described in developmental terms involving the body. It is not simply the highest activity of the body, but it must also be thought of as a peculiar union between the realization of the body's capacity and nature's capacity. It is a sort of new dimension, or atmosphere, into which, when the body grows, everything else grows along with it. It is real, like space, one might say. But things, instead of being placed above or beside one another, as in space, are put into a series of implications and meanings. Logic becomes possible by virtue of reason and the possibility of rational living is open to man. Reason is one of the finest fruits of life, and because of it both man and the world are enabled to enter upon a new development.

[2] Aristotle, *De Anima,* Bk. II.
[3] Aristotle, *Posterior Analytics,* Bk. II, Ch. 19.

7. Thought as Play Activity

Although thinking developed as a biological character of important survival value in man's evolution, it becomes a play activity at an early stage. Curiosity is the name applied to idle attempts at thought; curious people pry into things for the fun of it. A person who has a disinterested love of knowledge is more curious in character than most of his fellows. Society has come to realize that such people are very valuable. A man may play cards or golf and nothing very startling result beyond the pleasure of a diverting recreation or a healthful exercise. To play with meanings or ideas is a far more potent sport. The ancient Greeks in their mathematics played with the highly impractical subject of conic sections, and men centuries later wore spectacles the lenses of which were cut according to the principles which their playful thinking discovered.

Thought, of all man's activities, has the highest potential. To play with ideas is like playing with dynamite. This fact gives scientists and philosophers their significance. A philosopher is a man who has a playful attitude toward meanings. Not only may the specialists in knowledge develop theories which posterity may find very valuable, but, if they work improperly and develop false theories, a whole social order may be systematically misled. Man must be taught to think properly, and those who have a knack or special ability should be encouraged to refine that knack into an art. The capacity for sustained and profound insight is an attribute which is far too rare to be neglected.

8. The Use of Symbols in Thinking

In the development of intricate internal adjustments the *rôle* of vocal mechanisms is important. Speech points the way. It indicates the activities to follow. Words are used as symbols or signs of certain meanings, or implications, which the items of experience possess. Language develops hand in hand with knowledge, both in the individual and in the race. It is indispensable to thought and its communication. It is, essentially, a set of artificial signs organized for the purpose of fixating and conveying meanings. A high degree of civilization is impossible without elaborate systems of intentional signs. Natural signs are useful but cumbersome. Flexibility in transference of meaning is facilitated by spoken language, which consists of sounds made by man's respiratory apparatus which are indefinitely variable and controllable. Written language fixes transitory speech in preservable form.

Thought embalms itself in diction. The nouns indicate the core of meaning involved in the items of our experience, which is then further

qualified by adjectives. Verbs, prepositions, and conjunctions indicate that these items are, and how they are, relevant to the situation in question. As more and more inclusive items come to be discussed, language tends to become more technical. Symbols are invented which have very wide applicability and great exactness. Formulas result from which verbs are excluded, such as $\frac{1}{t}$, the formula for velocity. In formulas only the terms remain, with certain dynamic connections indicated. Science translates man's descriptive accounts of experience into the vocabulary and syntax which make these propositions readily available for the purposes of inference, indicating the substitutions which may be made and the controls which may be effected.

9. The Definition of Terms

In order that thinking may go on precisely and meanings be handled without confusion it is necessary that definition take place. Not to mean one thing is to mean nothing; terms which wobble are worse than useless in that they may be positively misleading. In effecting a definition in correct thinking, the term which may be the subject or predicate of a statement may be used in two ways: denotatively or connotatively. When used denotatively, or extensively, a term simply points out the subject-matter without qualification, such as, *That* is a man. The connotative, or intensive, use occurs when the term qualifies the subject-matter, or items already denoted, by the attribution of additional meanings, such as, This man is an *Indian*, or, This Indian is a *squaw*. It should be noted that most terms have both denotative and connotative uses. Denotatively a term indicates the subject-matter to which it applies; connotatively it indicates the qualities which it implies. *A term which has been accurately distinguished both intensively and extensively is said to be defined;* the meaning has become precise. This is what is meant by clearness. The term is completely and clearly defined when it is distinguished adequately from kindred concepts and when the qualities implied by it are fully grasped.

There are various kinds of definitions. *Connotative, or descriptive, definition* sets forth such a combination of properties as to make the object readily recognizable. This is the type most frequently found in dictionaries. *Logical definition,* in a narrow sense, is one form of this which refers the term to its proximate genus and states its differentia, *e.g.,* An animal is a living being having sensibility and the capacity of locomotion. *Genetic definition,* another form, explains the process by which the thing referred to is, or has been, produced, *e.g.,* The dirigible is a lighter-than-air craft developed out of the balloon and the internal-combustion motor. *Etymological definition* states the root meaning of the words used, *e.g.,*

Psychology (ψυχή + λόγος) is the science of mind or soul. *Denotative, or illustrative, definition* is frequent in the classroom. The kind of objects to which the term applies are indicated, as in the illustrations of the other kinds of definition which have been given above.

The chief rules to be remembered about definitions are: (a) good logical definition refers a term to its proximate genus, *i.e.,* next higher class, and states its essential differentia; (b) a definition should be neither too broad nor too narrow in the genus or differentia employed; (c) it should be as concise, simple, and direct as possible; (d) a term should be defined in other than cognate or synonomous words; (e) definition should be expressed whenever possible in positive rather than negative terms.

10. Fallacies In the Use of Language

As a result of the historical effort to make terms precise in meaning, a number of fallacies have been distinguished which are known as fallacies of equivocation. *Ambiguity* is the neglect of important relevant distinctions in the use of terms, *e.g.,* The tenant asked his landlord to *release* him. *Amphiboly* is a form of fallacy in which the ambiguity is inherent in the sentence structure, *e.g.,* "Wanted: a chauffeur for an automobile with no bad habits." The *fallacy of composition* is the name given to the mistaken attribution of the qualities of a part to the whole of which it is a part, *e.g.,* 15 is an odd number; therefore, 15 plus 15 equals an odd number. The *fallacy of division* is the converse of this: 30 is an even number; therefore, half of 30 is an even number. The *fallacy of misleading accent* may occur in spoken language, *e.g.,* The President says the *Senator* is an idiot, and *The President,* says the Senator, is an idiot. In written language punctuation would straighten out the ambiguity; accent is the punctuation of speech and may therefore mislead. The *fallacy of abstraction* occurs when one takes abstract terms as indicating existing objects in the sense in which concrete terms do. To think of the "common will," "public opinion," and "destiny" as perceivable *existences* is to fall into this fallacy.

There are a great many other sources of confusion among which may be noted the similarity of sounds among words, *e.g.,* "bemean" and "demean," and differences of meaning of the same word to different people, as with "scholar," "justice," and "gentleman." In England, for example, a "gentleman" is a "man who lives without working." Theodore Roosevelt is reported to have said of some political opponents, "They are gentlemen; they bathe regularly and do not steal." It is important that the words used in discourse reveal the exact meanings attaching to the existences under consideration. Anything more or less than this detracts from the

true character of scientific thinking. Words must not interfere with thought by distorting the subject-matter to which they refer, else they defeat their own purpose. Words are instruments, not the subject-matter itself, excepting in philology. " Words," said Hobbes, " are wise men's counters, they do but reckon by them; but they are the money of fooles."

II. Perceiving and Thinking

No abstract distinction is more difficult for the uninitiated than that between *perceiving* and *thinking*. The inability to be reflectively thoughtful makes philosophy seem a hopeless, confused jumble of meaningless phases. Plato expressed in a beautiful figure this confusion which an untrained mind feels when confronting for the first time the world of thought. He says,[4]

> Behold! human beings living in an underground den, which has a mouth open towards the light and reaching all along the den; here they have been from their childhood, and have their legs and necks chained so that they cannot move, and can only see before them, being prevented by the chains from turning round their heads. Above and behind them a fire is blazing at a distance, and between the fire and the prisoners there is a raised way; and you will see, if you look, a low wall built along the way, like a screen which marionette players have in front of them, over which they show the puppets.

Behind this wall, in Plato's picture, men are passing, holding up all kinds of vessels, statues, and figures of animals, which are visible over the wall. Some of the men are talking. The prisoners of the cave see only shadows, grotesque shapes which the fire throws on the opposite wall of the cave. Furthermore, the cave has an echo, and the talking of the men carrying the figures is attributed by the prisoners to the flitting shadows on the wall. Their knowledge, according to Plato, is literally nothing but the shadows of images. But suppose the prisoners are released! Plato continues:

> At first, when any of them is liberated and compelled suddenly to stand up and turn his neck round and walk and look towards the light, he will suffer sharp pains; the glare will distress him, and he will be unable to see the realities of which in his former state he had seen the shadows; and then conceive some one saying to him, that what he saw before was an illusion, but that now, when he is approaching nearer to being and his eye is turned towards more real existence, he has a clearer vision, — what will be his reply? And you may further imagine that his instructor is pointing to the objects as they pass and requiring him to name them, — will he not be perplexed? Will he not fancy that the shadows which he formerly saw are truer than the objects which are now shown to him? . . .

[4] Plato, *Republic,* Bk. VII (Jowett's translation).

> And if he is compelled to look straight at the light, will he not have a pain in his eyes which will make him turn away to take refuge in the objects of vision which he can see, and which he will conceive to be in reality clearer than the things which are now being shown him? . . .
>
> And suppose once more, that he is reluctantly dragged up a steep and rugged ascent, and held fast until he is forced into the presence of the sun himself, is he not likely to be pained and irritated? When he approaches the light his eyes will be dazzled, and he will not be able to see anything at all of what are now called realties. . . . And first he will see the shadows best, next the reflections of men and other objects in the water, and then the objects themselves; then he will gaze upon the light of the moon and the stars and the spangled heaven . . . last of all will he be able to see the sun. . . .

Plato points the moral to his own story; " the prison-house is the world of sight, the light of the fire is the sun, and you will not misunderstand me," he says, " if you interpret the journey upwards to be the ascent of the soul into the intellectual world."

12. Existence and Subsistence

This distinction between the " world of sight " and the " intellectual " world, to use Plato's terms, has been prominent in philosophy from his time to the present. A common way of expressing, in contemporary usage, this contrast between the world of sense and the conceptual, or intelligible, world is to employ the terms *existence* and *subsistence,* using *reality* as the inclusive term. A diagram brings out the subdivisions clearly.

Reality

Existence	*Subsistence*
The world of *sensed* things: objects grasped by the senses.	A. The world of the *conceptual* and the *possible*: all concepts and laws.
	B. The world of the *imaginary* and the *impossible*: all centaurs, round squares, etc.

Fig. 17. Existence and Subsistence

Everything, of course, is somehow *real. Existence* includes those features of our experience which are detected by seeing, hearing, tasting, smelling, and touching. *Subsistence* refers to all ideas, notions, concepts —

indeed, everything over and above the realm of perceived things. Without going too far into the metaphysics of the matter, it is possible to point out that there are things which have reality but are not perceived, such as numbers and the law of gravitation; and that there are other things which are real but are not thought. The odor of *narcisse noire* merely *is,* when it is; and it *is* in a different way from the number ten, which also *is,* when it is. The so-called world of existence is essentially the natural environment of a man with which he is biologically fitted to come to terms, while the world of subsistence, the conceptual world, is the stock of methods, notions, forms, or ideas which constitutes the intellectual core of his civilization. However past philosophers may have pictured it, as scaling the dizzy heights of "pure being," or what-not, the conceptual world is the world of discourse which we acquire by education. It is the store of meanings which is carried along progressively by human society. Into this conceptual world and the methods by which it is developed the succeeding chapters will delve a little deeper.

P. W. W.

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CHAPTER IX

OBSERVATION

Observation is the dominant aspect of two phases of the thinking process. (1) *The initial exploratory observation which furnishes the suggested hypothesis* is the first of these. (2) *The experimental observation and manipulation used in following out an hypothesis* is equally important. In scientific procedure we observe anything relevant to the investigation in progress. The factors, whatever they may be, upon which reasoning is consciously based, are said to be observed. Thought begins and ends in the observation of things.

1. The Nature of Facts

The term *fact* is assigned to the factors which pose a problem. Facts are things assumed as *done* (from Latin *facere*); they are *data* (from Latin *dare*), or things *given*. For the purposes of thinking, something must be taken for granted. The things so assumed, whatever the degree of analysis to which they are subjected, are called facts. By this it is not meant that all people will accept the same " facts " in the same situation. The relativity of our discourse is accepted here as axiomatic; discourse has habits peculiar to itself. As we have seen above, tradition provides each man with a stock of funded meanings. A group of natives carrying rubber out of the heart of Africa, if one of their number were killed at a certain spot by a falling tree, might travel miles out of their way thereafter to avoid that location because of the evil spirits haunting it. The place would be *taboo*. Mumbo Jumbo, and other imaginary objects, are accepted by them as existential. To a civilized man such an accident would occasion merely the examination of similar neighboring trees to see whether any of them were in danger of falling from the rottenness of their trunks. If any dangerous ones were noticed, they might be pulled down, or they might be watched carefully in passing. But it would never occur to him that any spirit was after him. In his culture, Mumbo Jumbo is relegated to the domain of the imaginary, and he handles trees with an entirely different conceptual machinery. Facts, in other words, are often loaded. A meaning may be affixed to an event so readily that the fact appears in discourse as a whole nest of implications. Habit, tradition, and prejudice furnish the tags which are often clapped unreflectively onto the events of our world. It is for this

reason that an understanding of man's culture is essential to a comprehension of scientific method. We want rationality, not rationalizations of prejudices.

In an effort to escape the ambiguity of gross and complex data, modern science has tried to discount its prejudices by getting back to simple, unambiguous qualities which are distinguished, as well as may be, without any preconceptions. Descartes' *Discourse on Method* was the first of a large crop of writings on the nature and improvement of the understanding, all of which emphasized the necessity of reaching what Descartes called "clear and distinct ideas," *i.e.*, qualities ("impressions" was Hume's term) which are unambiguous, and, therefore, reliable for purposes of reasoning. In some spheres man, in fact, has stripped himself remarkably of his prejudices, and watches events of nature with an aloof detachment which facilitates greatly the detection of nature's secrets. "The facts" in physics and chemistry are the events which any scientist can produce in any laboratory, indeed which anyone can produce who follows directions, whether he knows what it is all about or not. In the more undeveloped fields of knowledge, this eulogistic meaning of the term "the facts" is not so apparent. Facts are more colored by preconceptions. This is really another way of saying that the fields concerned are undeveloped; for we mean by the development of a field of knowledge the progressive detection, by analysis and experimentation, by manipulation and substitution, of a body of reliable data. Arriving at such data is an achievement, for facts do not come with little tags around their necks, ready-made for use. They always have to be discovered.

2. The Suggestion of Hypotheses

Important events thrust themselves upon us so forcibly as to command attention. Birth and death, storms and eclipses, and other spectacular and sensational events have always impressed man vividly, while the humdrum framework of everyday experience is so habitual that, for the most part, we are unconscious of it. Sometimes, however, for one reason or another, familiar events are seen in a new way and become facts which figure in the formulation of new theories. Undoubtedly, the stones deposited by glaciers in the Alps had been seen for generations before the sharp-eyed chamois hunter, Perraudin, called attention to them as evidences that ice had covered the high peaks upon which they rested.[1] Hannibal's army, as well as Caesar's, must have passed many erratics without regarding them as such. At first Perraudin was laughed at, but when Agassiz visited the Alps, in the

[1] *Cf.* Williams, H. S., *The Story of 19th Century Science,* New York, Harpers, 1901, pp. 132 f.

summer of 1836, Perraudin's friend, Charpentier, called his attention to the theory, and a search for other evidences began. The " facts " were there; nothing but ice could have produced the erratics, and the scratches and polishings which were observed, not only in the Alps but all over the temperate zone. The notion of a Glacial Age was born, and it is now a commonplace of contemporary knowledge that the several ice ages came to an end about twenty-five thousand years ago.

In even more striking fashion some of the facts upon which the discovery of Halley's comet rested were present as recorded scientific data centuries before Halley was born.[2] In 1705 Halley explained how the parabolic orbit of a comet may be determined from three observations, and set about calculating the orbits of twenty-four comets. To his surprise the comets of 1607 and of 1531 had the same orbit as that of 1682. Upon looking up the astronomical records (" facts " which were already recorded) he found that comets were reported in 1456, in 1380, and in 1305. The intervals were, in each case, seventy-five or seventy-six years. It was impossible to doubt that here was an identical body, planet instead of comet, with an ellipse for an orbit instead of a parabola. Halley did not live to see the " comet " again; he died in 1742. But Clairaut, working with Lalande, and assisted by Madame Lepaute, predicted the perihelion of the returning comet for April 13, 1759, claiming a license of a month for inaccuracies in calculating perturbations. The heavenly wanderer arrived at its perihelion on the 13th of March, 1759. Another series of facts had been made intelligible and a basis of prediction established.

The way in which observations may suggest theories is further illustrated by the discovery of anesthetics. Here parallel work was carried on. Dr. Horace Wells, a dentist of Hartford, Connecticut, in 1844 used nitrous oxide to dull the pain of pulling a tooth.[3] Dr. W. T. G. Morton, of Boston, then deliberately experimented for a number of months on the theory that other allied drugs would do the work better. Finally he performed, with sulphuric ether, a number of experiments upon animals and dental patients which convinced him that he had solved the problem of painless surgery. On October 16, 1846, Morton anesthetized a patient of Dr. J. C. Warren, a Boston surgeon, for a major operation, and the patient slept quietly throughout the entire ordeal. Upon the publication of this discovery of ether as a successful anesthetic, a Dr. Long, of Georgia, came forward to announce that he had used ether for some years in his own medical practice. While a medical student he and some of his fellow students had experimented with the effects of various drugs upon themselves and, on one

[2] *Cf.* Whewell, William, *History of the Inductive Sciences,* London, Parker and Son, 1857, Vol. II, pp. 181 f.

[3] *Cf.* Williams, H. S., *op. cit.,* pp. 365 f.

occasion, after inhaling ether, he had accidently fallen over a piece of furniture in his room and severely lacerated his shin. He felt at the time only the pressure of the impact, no pain; but in the morning he discovered a badly damaged leg which required careful treatment. This gave him the idea that ether deadened pain — in this case the actual observation of the fact came first — and he used ether subsequently on his patients. His notion had been, however, that only certain people were susceptible; and for this reason, probably derived from irregular administration of the drug, he had failed to publish his discovery to the medical profession.

It is impossible to go through the history of science without realizing that in many instances observations have almost forced scientific advances, and that the deliberate, careful development of experience by manipulating and substituting factors in conscious experimentation has been sporadic rather than systematic up to comparatively recent times. Indeed, modern science began when systematic sustained research was attempted, and not before.

3. Testing Hypotheses by Observation

Perhaps no scientist has had a more perfect method than Sir Isaac Newton (1642–1727). His *Opticks,* first published in 1704, contains excellent examples of method; controlled observation and accurate theorizing are to be found on page after page. One of his first experiments was to take a prism and pass a ray of light through it, allowing the refracted ray to fall upon a white paper on the opposite wall. There he found an oblong strip of color with semicircular ends instead of the patch of white color which a ray of sunlight normally makes on a plane surface. His care is well illustrated by the following passage: [4]

> I tried the same Experiment with other Prisms with the same Success . . . and because it is easie to commit a mistake in placing the Prism in its due posture, I repeated the Experiment four or five times . . . the different Magnitude of the hole . . . and different thickness of the Prism where the Rays passed through . . . and different inclinations of the Prism to the Horizon, made no sensible changes in the length of the Image. Neither did the different matter of the Prisms make any: for in a Vessel made of polished Plates of Glass cemented together in the shape of a Prism and filled with Water, there is the like Success of the Experiment according to the quantity of the Refraction.

Newton chose to think that the colors were already in the white light, and were produced by the decomposition of the latter, rather than to suppose that the color came from the glass itself. On seeing that the blue end of the rainbow band of color was displaced further than the red end, he

[4] Newton, I., *Opticks,* London, Smith and Walford, 1704, pp. 20 f.

inferred that blue light had greater refrangibility than red light. Placing a second prism at right angles to the first, in the path of the refracted ray, he saw upon the wall a further displacement of his oblong strip of color; — again the blue was refracted further than the red, and his inference was thereby verified.

Now, said Newton, if it is true that the colors are all in the white light, and that white light is really the combination of all the colors, then the recombination of the colors will give white light again. So he took two prisms and placed them side by side, allowing the ray to go through the second one so that it would be refracted back into its normal path; upon the wall there appeared the usual patch of white light. Not content with this verification, he cast the spectrum upon the wall again and arranged seven little mirrors so that they reflected the colors of the refracted ray back upon another surface, focussing them at a given point. There, upon the second surface, appeared a spot of ordinary sunlight. By such careful observation and analysis, Newton built up his theory of color.

Newton's work was of the sort which any experimenter could reproduce with any similar equipment. In fact, his experiments were tried by many others, and his theory became authoritative in a short time. Yet a century later Goethe (1749–1832), the famous German poet, attacked his theory of color.[5] His primary experiment consisted in looking through a prism at a white wall; the wall, he thought, on the Newtonian theory, should be seen in rainbow colors, whereas all was white excepting a band of red on one side, and one of blue on the other. His scientific friends tried to point out that this was to be expected on Newton's hypothesis, since all the rays would be refracted together to one side or the other, with the narrow strip of red lagging behind, and the edge of blue projecting beyond the others. Goethe seems to have been incapable of reasoning the matter out in this fashion. He reiterated his attack on Newton, calling his reasoning "impudent" and even accusing him of lying about his experiments. Strange to say, Goethe thought that he had discredited Newton, which seems to have been his real aim, and that he had made a great contribution to science. A better illustration of the spectacle a man can make of himself, when he strays out of the field in which he is master of the approved technique, can scarcely be imagined. Newton's theory of color is more firmly established now than ever, and Goethe's invasion of a field in which he was merely a tyro is regretted by those admirers of his literary ability who are aware of it.

[5] Goethe, J. W. v., *Geschichte der Farbenlehre,* 1805, published in final form in 1810.

4. Some Hindrances to Observation

One of the most common sources of error in observation, particularly with those who, like Goethe, are unskilled in careful work, is the fact that men tend to remember the items which are favorable to their own prepossessions and to forget the negative evidence. This cannot be reiterated too frequently. There must be checks and balances introduced into our method to offset the unconscious selection which tradition and habit carry on. As Sir Francis Bacon (1561–1626) put it, " Men mark when they hit, and never mark when they miss." Bacon recounts the story [6] of the man in ancient days who was brought into a temple filled with the portraits of those who had paid their vows before going to sea, and had not been drowned. Upon being asked to acknowledge the power of the gods to preserve mariners from shipwreck, this ancient skeptic replied, " Aye, but where are they painted who were drowned after their vows? " This is the kind of inquisitiveness which a good investigator must have. Far from being too skeptical in temper, the average man is too credulous.

In a recent ethical research project some experiments were performed in a New Jersey city to determine the character of children in various groups.[7] Tests were employed to bring out such character traits as honesty and veracity; and it was found, among other correlations, that the children in this city who were members of Sunday Schools were superior in moral character to those who were not members. Less careful observers would have jumped to the conclusion that here was a demonstration of the ethical value of Sunday School training, and that the influence of the Church was the occasion of this higher level of moral attainment. But this was not true. Upon further analysis it was found that those who were listed as Sunday School members, but *did not attend,* were of as high moral character as those who did attend. The evidence indicated that attendance at Sunday School was a negligible factor in character development, but that the better families in the community had their names on the Church records. The effective factor had been, of course, the training of the children in their homes.

Bacon also said [8] that " by far the greatest hindrance and aberration of the human understanding proceeds from the dullness, incompetency, and deception of the senses." Perhaps he was right; certainly there are very definite limits to man's field of perception. Some things are beyond our apprehension. Undoubtedly there are many natural qualities which our sense organs do not grasp at all. Certain other animals surpass us notably

[6] Bacon, Francis, *Novum Organum,* 1620, Bk. I.

[7] Hartshorne, Hugh, and May, Mark A., *Studies in Deceit,* New York, Macmillan, 1928, pp. 357 f.

[8] Bacon, Francis, *op. cit.,* Bk. I.

in smelling, hearing, and seeing; and some of them may be equipped to sense qualities of which we are totally oblivious. Our sense organs are the product of a long evolution and are adapted to adjusting us with reference primarily to certain basic needs. The practical character of their origin may well have prevented the development of a sensitiveness to other possible items, where that sensitiveness might have been a hindrance to biological survival.

The hindrances to correct observation may be summed up under three heads. (1) *Physical:* imperfect instruments, colored or dim light, inaccessibility of the material, and such similar factors. (2) *Physiological:* bad health, fatigue, defective sense organs, and the like. (3) *Psychological:* lack of technical training, general ignorance, strong prejudices or prepossessions, temperamental peculiarities or abnormalities of the individual mind, bad memory, and other items of the same sort.

5. Instruments and Observation

The best that man can do is to make use of the equipment which he has. His natural organs may be extended in their uses by instruments; this is the true meaning of instruments. Telescopes and microscopes are extensions of our vision; telephones, of our hearing; tools, of our hands. In the words of Bacon, " For as in ordinary life every person's disposition, and the concealed feelings of the mind and passions are most drawn out when they are disturbed, — so the secrets of nature betray themselves more readily when tormented by art than when left to their own course." An Associated Press dispatch of October 21, 1926, described a remarkable bit of observation conducted recently with elaborate apparatus. Dr. W. D. Coolidge, of the General Electric Company, experimenting with cathode rays, was enabled to pass them outside his newly-developed tube in sufficient force to make them visible as a purple glow for a foot or more in front of the foil window through which they were cast. A current of 350,000 volts was used. In a darkened room, crystal of calcite, Iceland spar, was made to glow with a bright orange color which lasted for several hours, after only a few seconds of exposure to the rays. A lump of dolomite was similarly affected, excepting that the marble glowed with a pink color. Granite became iridescently luminous with greens, blues, and yellows, but darkened as soon as the rays were turned off. Strangest of all, acetylene gas, sealed in a glass tube, when exposed to the rays, was immediately reduced to a yellowish-brown powder which has no known chemical solvent. The tube used is of glass, four feet long, with the usual spherical bulge in the center. The cathode is heated by a spiral filament, and the interior, as in the ordinary X-ray tube, is as nearly a vacuum as is possible.

A few days after the announcement of these observations, Dr. Millikan stated that the so-called "cosmic rays" really had been observed again and were to be distinguished carefully from the cathode rays.[9] The former are a high frequency light, ethereal in character, and are not corpuscular, as are the cathode rays. They come from outside the earth at a frequency so high that they will pierce a wall of lead twenty feet thick. The observations of 1926 on this particular subject were made in the Andes Mountains. In Bolivian lakes, some 16,000 feet high, the recording electroscopes were submerged in water and the observation of the rays was effected. Other observations were made by self-recording electroscopes sent up in sounding balloons which reached nine-tenths of the way to the top of the earth's atmosphere. On march 17, 1928, Dr. Millikan said,[10]

> When it is remembered that the positive electron is the nucleus of the hydrogen atom, and that all the spectroscopic survey of the heavens shows the extraordinary abundance everywhere of hydrogen; and when we reflect that we have known for fifteen years that all the elements have weights that are practically exact multiples of the weight of the hydrogen atom as it appears in the structure of helium the . . . conclusion that the process of atom-building out of positive and negative electrons (the latter have a mass that is negligible in comparison with the former) is now going on gains additional plausibility. . . .
>
> Putting together, then, the quantitative and the qualitative evidence, we may have some confidence in the conclusion that the heretofore mysterious cosmic rays, which unceasingly shoot through space in all directions, are the announcements sent out through the ether of the birth of the elements.

Millikan's attention was first called to these rays in 1910 by reading that a Dr. Gockel had observed very short rays, similar to those of radium, at high altitudes in a free balloon. Knowing that radium radiations could not reach high altitudes, he thought of the fascinating hypothesis that these rays came from above. The use of sounding balloons and of electroscopes in lakes of high altitude were experiments incidental to the determination of the intensity of the radiation.

In 1925 Millikan made some very nice observations. He observed the depth to which the rays reached in Muir Lake, Mount Whitney, California.

9 A. P. dispatch to *The New York Times,* October 29, 1926.

10 Special dispatch to *The New York Times,* March 18, 1928. *Cf.* Armagnac, Alden P., "Discovering the 'Cosmic Rays,'" in *Popular Science Monthly,* July, 1928. (Since this was written, an address by Dr. Millikan, on "Available Energy," delivered on September 4, 1928, has been printed in *Science* for September 28, 1928, New Series, Vol. LXVIII, No. 1761. In this he suggests that the cosmic rays represent a return to the stars of the energy radiated by them into the depths of space.)

He then sank his electroscope in Arrowhead Lake, 6700 feet lower in altitude than Muir Lake. The 6700 feet of air by calculation should equal six feet of water in their absorptive power. If, then, the rays came from the heavens, the readings in Arrowhead Lake should be, at the depth of one foot, the same as those at a depth of seven feet in Muir Lake. Strikingly enough, the difference in readings between the two lakes was six feet, taken all the way down! This proved that the rays were from beyond the earth. His subsequent tests proved that the rays are not solar and that they always have the same intensity at similar altitudes. They are 1/100 the length of radium rays, and are the most penetrating radiations known. His hypothesis is that they are the waste energies left over from the cosmic process of the transmutation of elements.

If the growth of that part of our culture which we call concepts and laws is a matter of the development of the social environment, it is equally true that the accumulation of observations is a matter conditioned by the development of the environment. Elaborate paraphernalia is a prerequisite to subtle analysis and experimentation. Neolithic man had a brain as good as ours; indeed we are descended from him. But he never could observe cathode rays emanating under the pressure of 350,000 volts; nor could he have sensed the cosmic rays of Millikan. *The instrumental equipment is crucial in observation.* The history of many of the sciences could be written as an account of the development of experimental apparatus. By means of instruments, events are not only tricked into repeating themselves, but new combinations of materials may be effected which never before occurred. Events may be both produced and observed. Not by accident has man been called *homo faber* as well as *homo sapiens.* He not only observes facts; he makes them.

6. The Importance of Control in Observation

It is impossible to overemphasize the scientific importance of controlled observation. All the logic books and works on scientific method preach the importance of *analysis* and *experimentation;* and not without reason. Experimentation is the *controlled* testing of a theory by the observation of its consequences in operation. It is obvious that such careful work as that of Newton carries conviction with it. And it does this without endless repetition of the same experiment. The secret of scientific advance is not so much in experimental repetition as in experimental control. *Where the control of conditions is complete, a scientific law may be achieved with a single experiment.* An essential relation between two factors may be completely revealed in one adequately controlled situation. If sunlight is really composed of all the colors of the spectrum, one detection of it is enough

to make us regard it as such thereafter. Not only is experimental control a matter of intellectual economy, therefore, whereby one case stands theoretically for all cases, but practically, in the applied sciences, such as medicine, experimental control in one case means the control of all such cases. If one can really control one case of yellow fever, one can control all cases. The universality is in the control factor, and the experimental repetition in the laboratories is to insure that the materials are really typical materials. *A statement of what happens when typical materials are under controlled observation is universally true.* Such materials will always behave in such a manner. This is called *the axiom of the uniformity of nature.*

7. Conclusion

Observation, logically considered, is the process by which some portion of our experience, some kind of reality, is controlled and elaborated for the purposes of knowledge. In scientific observation, the subject-matter is carefully analyzed; that is, the given material is torn apart into its constituent parts so that they may be more thoroughly inspected and their organization recorded. Where experimentation is possible, and is attempted, the factors distinguished by analysis are manipulated and substituted in such a way as to afford a constant check on the hypotheses used. Unquestionable knowledge can be achieved where thorough experimental manipulation and substitution are possible; indeed, the growth of exact knowledge is almost synonomous with the extension of the experimental method. The development of instruments aids analysis and experimentation. Together with this extension of man's powers of observation goes the laying aside of prejudices. Any strong emotion renders us credulous as to the existence of objects suitable to it.

As an aid to precision, it is important to use exact records, mathematical in character where this is possible. Mechanical recording devices are frequently used. Any means should be employed which aids in facilitating our knowledge. As a basis for accuracy in science, there must be exactly recorded observation of precisely defined data. These are the *sine qua non* of scientific advancement.

P. W. W.

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CHAPTER X

JUDGMENT AND INFERENCE

1. Some Aspects of Thinking

The thinker, as we have seen, is an alert observer; he is at the same time an interpreter. It is between observing and explaining things that the thought life of man commonly pulsates and develops. These complementary activities are the indispensable feet upon which the explorer advances into the kingdom of truth. The casual notice of a scratched or erratic stone is of trivial and passing import until some reason is found for its peculiarities; until it is interpreted perhaps as the token of a vanished age of ice.

Knowing a thing, then, is more than seeing it. A child may chance to look at an erratic boulder; only a geologist really comprehends it. We are blind to a host of phenomena because reflection has failed to turn upon them the light of some general explanation. Knowledge grows as interpretation illuminates perception and perception supports interpretation. One can see a falling apple but one must infer the universal law of gravitation. Very familiar things, such as the parables of Jesus, the *Sistine Madonna,* or herbaceous peonies, which seem stripped of meaning, sometimes surprise us with fresh significance when we connect them with some new experience, principle, or historical fact. The whole business of thinking consists in weaving the beads of concrete things into the significant patterns of thought. *Seeing without understanding is vain and understanding without data is impossible.*

From the study of observation we turn now to the principles of understanding. We are in search of the basic forms and criteria of thinking or knowing when it attains clear expression. *We take thinking to comprise all mental activities which aim at or yield knowledge.* Much thinking never attains overt form. I may judge, for example, that a bookcase is too heavy to lift or tea too hot to drink and act accordingly without articulating my thought in words. But if I meet obstacles, or desire to preserve, communicate, or analyze my thought, I fixate it in propositions. Propositions are the vehicles of thought through the generations of men. As the expression or deposit of living thought, they provide raw materials for logical anatomy.

Much thinking, too, is nebulous, spasmodic, or circuitous. But the logician is concerned with the critical and connected advance which thought makes, regardless of its practical and emotional detours. An airplane, a

geometrical solution, or a social institution may represent years of intellectual travail, and yet the rationale of each may be epitomized into a few sentences. A comparative analysis of these reduced forms shows that certain types of reasoning commonly recur. The logician is interested in abstracting and defining tersely the ideal forms of fruitful thinking. The structure and the validity of thought are his fundamental concerns. This and the three following chapters are devoted to these two problems.

2. Judgment as the Unit of Thinking

Logicians, loving simplicity, as other scientists do, long ago sought an elementary and universal form of which all the varieties of thinking might be conceived as modifications. Such a form would be exceedingly convenient in finding our way amid the countless variations which language, diction, and subject-matter impart to thinking. Grammarians explain all grammatical structures in terms of the sentence, and have reduced its components to eight parts of speech. Is there not an irreducible unit of explanation in logic, like the sentence, or like the cell in biology and the atom in chemistry? We agree with many logicians in holding that such a primary notion and master key to thinking exists in the judgment.

I think when I face a troubled situation which I am interested in managing: Which road shall I take? What is the best location for the new store? What kind of plant is this? I study the factors which seem relevant to the problem and look for a solving idea. Every step towards the solution brings the activity of the mind to a focus, and an assertion results, such as: I will follow the left road because it runs northward; or, I think this location is too far from the center of population. The affirmation which answers my question is called judging or judgment. The latter term is applied both to the dynamic activity itself and to the content or proposition asserted.

Judging in this sense of interpreting what is before us is the constant occupation of an alert mind. Bosanquet declares, "Whenever we look or listen, and *notice* features and qualities in the perceptions that arrest the eye and ear, we are rapidly and continuously judging."[1] We are steadily judging also when we are engaged in any kind of work where quick solutions of difficulties are demanded, as in buying or selling merchandise, defending a client in court, playing football, or flying an airplane. *Thinking is a collection or train of judgments.* The developing forms of judgment from simple perception to the most complicated chains of reasoning include all varieties of thinking.

[1] Bosanquet, Bernard, *The Essentials of Logic,* p. 106; copyright 1920 by the Macmillan Company. Reprinted by permission.

Judgment may be defined as the mental act of asserting (affirming or denying) that something holds good of something else. It is the act of characterizing an individual object by a definite idea, as in declaring: *This tufted pansy is black, Moses was a prophet,* or, *Celluloid is composed of camphor and guncotton.* Anything that is meant to be true, or anything that can be denied, is a judgment. Judgment is the crystallizing of a freshly gained insight into a presented situation; rather, it is insight itself forming and formulated. Some of its important characteristics will now be indicated.

3. The Analytic-Synthetic Function of Judgment

The essential function of judgment is the grasping of a unity in a diversity, or of differences in a whole. This function is simply illustrated by a recent psychological study of a dog and a child at play. For playthings they had on the floor a lot of scattered apples and a basket. The dog played with one object after another in a haphazard way. The revolution which signalized the birth of thought occurred when the child put the apples into the basket and in this way carried them to a place of safekeeping. In this original act the child showed that he was beginning to distinguish objects and to connect them into a meaningful relation. He constructed elementary judgments also when he said, "This is good," or "That is red." *Judgment is the linking of terms in any significant way whatever,* as in identifying, perceiving, characterizing, or correlating them.

An act of judgment manifests that union of differentiation and synthesis which marks all thinking, which indeed is thinking. On the one hand, judgment, and therefore knowing, would be impossible if the mind had not developed far enough to discriminate among objects, however vaguely. In judgment some element in an implicitly complex experience is fixed upon, brought forward attentively, given a greater distinctness in consciousness, and perhaps named. "*Any consciousness,*" says Bowne, "*which has passed beyond the stage of unqualified, unrelated feeling and become a consciousness of something has already reached the stage of judging.*" [2]

On the other hand, judgment and knowing would be impossible in a multiverse of innumerable parts if these somehow could not be truly comprehended and organized, however uncertainly. A whiff of fragrance, a thorny prick, and a feeling of satiny texture do not, as a succession of sensations, constitute a rose. I know the rose only as I can consolidate these and other elements, and think of them as coexisting to form an individual whole. The analytic-synthetic work of thought is more strikingly illustrated

[2] From Bowne's *Theory of Thought and Knowledge.* Copyright. By permission of American Book Company, Publishers.

in such achievements as tracing the cycle of wheat rust or charting the path of a planet. Judgment consists at once of breaking up a given whole into elements and of reuniting these at a higher level of clearness and individuality.

In the judgment, then, the mind exhibits its marvelous power at once of making distinctions and of connecting these into significant assertions. This power may manifest itself in perceiving objects, building concepts, adjusting means to ends, harmonizing the details of a work of art, or in deriving a scientific law from observed facts. Here is *thinking in its essence, the mental function that differentiates as it correlates, and that constructs out of our chaotic stream of experience an ordered world of definite objects and laws.* Judging is the unit of operation, the faculty of connecting parts into wholes and of understanding wholes by reference to their parts. Thinking cannot be reduced to anything more elemental than judging, thus conceived.

4. The Subject and Predicate in Judgment

While a judgment is a unitary act of mind, certain aspects of it may be distinguished. In the study of propositions and inferences it will be convenient to distinguish between subject and predicate (*S* and *P*). *S* is anything whatever in experience which may be identified or distinguished, however loosely, while *P* is any *idea* which is regarded as truly relevant thereto.

It is easy to fall into the mistake of treating *S* and *P* as simpler elements which are somehow juxtaposed to compose judgments. Attempts to picture their relations in mechanical or temporal metaphors are confusing. Judgment is not a mosaic of parts but a kind of spiritual union of significant assertion. Judgment is primary, and *S* and *P* are derivative aspects or functions of the judgmental whole.

The unity of the judgment resembles the unity of the sentence. In translating a difficult sentence in a foreign language we may know the dictionary meanings of all the words (and each of these discoveries would be a judgment) and yet be unable to fuse them into a meaningful whole. We may be surprised by the suddenness with which the separate words before us finally congeal into a significant assertion. Until this consolidation can be accomplished, however, we have not won the import of the sentence. There is some evidence that historically the sentence developed prior to the word. In primitive languages it is sometimes difficult to distinguish the word within the sentence. It is the sentence as a whole, with emphasis upon the verb, which expresses the individual's response to the concrete situation. In any case the sentence, like the judgment, functions

as a unitary whole, and explains the parts of speech which are integrated in it.

Subject and predicate are twinborn in the judgment. The subject of thought is always something that is being characterized in some way, perhaps only as a problem. Subjects (that is objects of thought) are neither revealed to us directly as substances without attributes, nor as subjects with a full dress of ready-made predicates. We possess them only as we construct them through long intellectual labor upon our developing experience. On the other hand, in genuine thought, we do not toy with predicates or ideas apart from prospective subjects. As Creighton asserts, " We cannot *think* a term without thinking something *of* it." [3]

5. Judgment and Concept

The idea or concept evidently is an integral phase of every judgment. Indeed, it is in the medium of the judgment alone that the concept actually exists. If we look at the meaningless word, *nadyc,* and then at a word containing the same letters, *candy,* we distinctly experience an emergence or increment of meaning which was lacking in the nonsense syllables. We have formed a simple judgment of recognition in the light of our past experience. If we had any momentary reason for doing so, we could proceed to make many assertions about candy. We saw in an earlier chapter how a concept is the consolidated result of many previous judgments and is symbolized by a word or phase. In other words, *a concept may be defined retrospectively as the set of our habitual judgments about an identical thing or class.*

The full meaning of a concept or an object is to be found in all the judgments we can develop concerning it. Thus, our concept of a Zeppelin airship is the set of affiliated assertions, tied by habit to this verbal sign, which in any way or at any time we could make concerning it; for example: it is lighter than air; it is composed of a row of gas bags enclosed in an elliptical cover; it is propelled by gasoline motors suspended in cars.

The value of the concept in mental economy lies in its permanent character. It serves as an enduring point of departure for future judgments. Advancing thought would have no foothold if experience were not thus pregnant with the usable deposits of past thought. " It is the fertile plurality of unachieved judgments which gives to the concept the appearance of self-sufficiency." *The concept may be defined prospectively as the abiding rule for identifying and dealing with the objects it connotes. It is the system of possible judgments about a class of things.*

[3] Creighton, J. E., *An Introductory Logic* (ed. 4), p. 338; copyright 1921 by the Macmillan Company. Reprinted by permission.

The meaning of anything, then, may be brought into consciousness either by reinstating the judgments that are implicit in an achieved concept, or by new and direct analyses of the objects themselves. Thus, the relation between judgment and concept is intimate and, in a sense, reciprocal: new assertions enrich a present concept or build a new one, while a concept which we already possess furnishes, as provocative occasions arise, a basis for fresh judgments.

6. Judgment and Reality

Judgment is not a bare utterance of words nor a chance association of ideas. In science, as in law, judging is the serious business of justly determining the facts of the case. In particular, to judge is to have before the mind an object about which a definite assertion is made. Thought always exhibits this remarkable characteristic of referring to something beyond the little-known neurological processes which are supposed to condition it. When I declare that oxygen is the most abundant element, my attention is not directed to any cerebral or psychic activity nor to these words as such, but to the reality which they represent. *Judgment always has an objective reference.*

Even when thought is concerned with such realms of supposition as artistic creations, juristic fictions, or mathematical postulates, the assertions made have all the marks of judgment except the conscious belief that they are true of actual entities. No genuine judgment is an arbitrary assertion in which I say anything I please, but an intelligent response in which I say what I can and must under the control of observed facts or of accepted assumptions.

The main business of thinking, then, is to interpret reality. Every time thought is crystallized into an express judgment, another stroke is added to the delineation of experience; some fresh portion of reality comes to be clearly revealed and defined. Judgment is reality as constructed and possessed by mind. It is the eye of thought surveying the world and the power of thought to build a significant universe. *Thinking, in short, is the sane and active mind at work making judgments concerning the real world.*

If judgments are true of real things, there must exist an identity of intelligible forms between mind and things, for, as McConnell asserts, "Nothing which mind cannot seize can ever be known. To be seized by mind, the object must be penetrated by relationships which reach the inmost essence." [4] Bosanquet declares also, "*The nature of mind is present in everything; the only difficulty is to see it there.*" [5] The seizing of an

[4] McConnell, F. J., *The Increase of Faith*, New York, Methodist Book Concern, 1912, pp. 56–57.

[5] Bosanquet, Bernard, *Logic* (ed. 2), Oxford, Clarendon Press, 1911, Vol. I, p. 231.

object by mind, the construction of it in intelligible form, is judgment. Judgment is the organ of knowledge-making. It is the only way in which truth and error exist.

We have said judgment always has by intention an objective reference. This reference, however, may be mistaken. The judgment may be prompted by desire or prejudice rather than commanded by the facts. Since judgment is an expression of free intelligence, predicates may be averred in a careless, indiscriminate, or opinionated manner. In this way arise the legions of biases and errors which the logician strives to subdue. Judging demands discretion and a sensible respect for relevant facts. The analysis of judgment clearly shows the locus of error and the need for evidence and verification.

7. The Nature and Stages of Inference

The task of science is to build systems of true propositions. A proposition, however, carries no internal signs of its own verity. Its validity depends upon its being supported or required by other facts or propositions. A multitude of private and custom-made assertions without any pedigree of evidence circulate widely among men. People often hold opinions for unknown reasons; they just have them — and they keep them because they like them. In science, however, " we cannot believe what we choose; we must believe what we can." The scientist insists that the true ancestry of propositions be revealed, whether forgotten or obscure, royal or banal. He will permanently adopt only those affirmations the descent of which, from the marriage of reality and of thought, is well attested.

A judgment whose logical parentage is explicitly set forth is an inference. The term *judgment* itself reflects or promises the weighing of evidence. The feeling in judgment that it could not be otherwise becomes articulate in inference. *The mental act of forming an assertion by definite reference to the facts or grounds which support it is inference.* It is any activity of thought which moves through a *therefore* or a *because.* The following are examples of inferences: This garment is better than that because the price is higher. Ice has one eleventh more volume than liquid water because it contains crystals joined by their corners or poles. The common barberry is a necessary host for wheat rust; this parasite may, therefore, be prevented by eradicating the barberry.

Between judgment and inference there is no break which marks the end of one and the beginning of the other. A logic could be built upon either. Inference is judgment with explicit reasons; judgment is an inference with implicit or possible reasons. In other words, an inference is also a judgment, but a complex judgment; a judgment is an incomplete (inchoate or

abbreviated) inference. The term *reasoning* is used as equivalent sometimes to inference and sometimes to a chain of inferences.

I infer, then, whenever I derive one judgment (*the conclusion*) *from another judgment or judgments* (*the premises*). I draw the conclusion because I discover between premises and conclusion a bond of connection which leads me to believe that if the premises are true, the conclusion is true. Suppose, for example, that I am lost in a forest. I study earth, sky, and wind for signs of direction. Perhaps I find a plant which I know grows only on the south side of a tree. If I remember enough about a map of the region to recall that safety lies southward, I infer the direction in which I should travel. My inference is true if I find my way out by going southward. Hence, Bosanquet declares, " When, by reason of one or more things that you know, you believe yourself to have arrived at the knowledge of something further, you claim to have effected an inference." [6]

The stages in the preceding inference are the stages of reflective thinking described in a preceding chapter. (*a*) The felt need of solving a specific problem initiates the process of inference. A *problematic situation* is one in which I want something but do not know how to get it.

(*b*) The second phase of inference is an *analytic attack* upon the presented materials in the hope of bringing order and meaning into them. James declares, " Whereas the merely empirical thinker stares at a fact in its entirety, and remains helpless, or gets ' stuck,' if it suggests no concomitant or similar, the reasoner breaks it up and notices some one of its separate attributes." [7]

(*c*) The third or *synthetic phase* of inference consists in discovering among the observed facts a connection which promises to solve my problem. In the above example the crux of the inference lies in fixing upon the abstract idea of southness. As soon as this idea is found to be common to two isolated situations, they are immediately connected and my position in the woods gains a definite place in the known geographical system.

(*d*) This constructive step completes the inference and is followed by other inferences aiming at verifying the hypothesis or organizing the results. These phases of *verification and systematization* will be discussed in later chapters.

The developing phases of inference are shaped and unified by the end to be achieved. Aimless day-dreaming or learning by rote are not strictly thinking at all. In genuine thinking we analyze, select, and connect data because of their seeming relevance to our purpose. The apes studied by

[6] Bosanquet, Bernard, *Implication and Linear Inference,* p. 2; copyright 1920 by the Macmillan Company. Reprinted by permission.

[7] James, William, *Principles of Psychology,* New York, Holt, 1890, Vol. II, p. 330; quoted with permission of publishers.

Köhler and Yerkes performed many acts which were perfectly fitted to gain their ends, and which had not been performed before. One of them, for example, inserted a stick into a tube and thereby pulled a remote banana into his cage. Another climbed on the shoulders of his keeper to reach a high banana. When the keeper immediately knelt down, the ape jumped off complainingly, took hold of the seat of his trousers, and tried with all his might to push him up. Thinking, then, is purposive in nature; it is intelligent will bent on so combining given materials as to reach a satisfying conclusion.

8. Implication and System

Implication is the most fundamental relation which can exist between two propositions. It cannot be explained in simpler terms, although it can easily be pointed out and illustrated. The following assertions express implications among facts. If air is excluded from a plant, it will soon die. If the products of 3^2 and 4^2 are added together, the sum will equal the product of 5^2. If cancer is a bacterial disease, its germs should be individual, isolable, and visible under proper conditions.

Statements of the kind just illustrated are called hypothetical propositions. They point to the striking fact that propositions do not stand alone. If one proposition is true or false, something else is always true or false. Such a relation is called implication. It is identical with logical necessity. It is variously represented: p implies q; if p then q; or, p therefore q. When all the accessories of inference are swept away, its constitutive framework is found to be a clear consciousness of how one thing is dependent upon or implied by another.

One thing implies another because of the systematic relations which exist in reality. Reasoning can find no more ultimate basis than this, and has need of none. *Inference is fresh insight into the way in which entities hang together in nature.* If we are acquainted with the structure of a system and know some of its parts, we may be able to infer other parts. If I know that hydrogen is lighter than air, I can infer that a free balloon filled with hydrogen will ascend in the air. When I see a dog with a long stick in his mouth stopped by a narrow gate, I say he does not think; he does not clearly perceive how the stick fits into the spatial arrangement of things.

In each of these cases a conclusion is inferred by discovering how discrete terms function as necessary and congruent phases in an organized whole. Necessary connection, or ground and consequent, exists only between elements within a system. Such trivial incidents as a cigaret stub, an open window, or an out-of-place book may be clues to a murder if they can be linked into an integral sequence of events. We must find the pervading

unity or principle of a system before we can pass from one member to another in inference. *"All inference, then, is within a connected system and consists in reading off the implications which this system imposes upon some of its terms."* [8]

Inference is the indispensable growing point of knowledge. We do not genuinely know an object until we understand how it is systematically related to many other things. This fact would be evident in answering the simplest question: What is a fossil? an eclipse? or the Fourth of July? If things were utterly discrete, chaotic, and haphazard, there would be no basis for inference, and its products would be either impossible or fictitious, and not true, as they should be. At the same time that inference presupposes order and continuity in the world, it enables us to comprehend more clearly the nature of that order.

9. Necessity and Novelty in Inference

The preceding paragraphs explain why the conclusion of an inference may be both new and necessary. At the same time that the conclusion goes beyond the facts or premises, it follows from them. This paradox is resolved by considering that in inference knowledge is developing. As the thinker moves forward to the conclusion he makes a discovery about the object in question; as he looks back at the premises he realizes the necessity of the conclusion. And both suffer a reciprocal illumination: while the conclusion is supported by the premises, it in turn helps to explain them. The necessity arises, as we have seen, from the way in which the real object is constituted; the novelty, from my seeing for the first time how it is constituted. Inference is neither a vain iteration nor a fortuitous combination of ideas.

This combination of novelty and necessity gives a peculiar charm to scientific thinking. Deference for reality is joined with deftness in creative imagination. A good reasoner needs at least three qualifications: *learning,* or abundant stores of information; *sagacity* in handling novel data; and *vigilance* regarding the adequacy of the evidence for his conclusions. The first ability makes thinking rich; the second makes it constructive; the last makes it true. While the products of imagination are new and those of memory are presumably true, only those of reason are both new and true.

10. Concluding Remarks Concerning Thinking

It should now be clear how inference is a complex or expanded judgment, a judgment based upon an explicit and necessary reason. But the

[8] Bosanquet, Bernard, *Implication and Linear Inference,* p. 10; copyright 1920 by the Macmillan Company. Reprinted by permission.

interests of the ordinary man center in the conclusions attained and he readily forgets the reasons or desires which gave them birth. Hence, in the ark of tradition are preserved many unsupported dogmas. Sometimes memory or critical investigation may regain the lost evidence, if it ever existed, and restore the judgments to well grounded assertions. Such assertions should make up the bulk of scientific knowledge.

Our general account of thinking is now finished. Judgment is the key to its understanding and inference is its most perfect expression. A cycle of thinking passes from problem to solution through dissecting and correlating activities followed by judgments of verification. Such cycles are actually realized with many degrees of completeness and irregularity in detail. A few typical kinds of inferences will be thoroughly discussed in the two following chapters. Yet perhaps our generic account will apply to all species of thought. *Thinking consists in constructing novel and more or less adequate answers to definite questions in the light of what we already know.* Reflective thinking as revealed in inference has a trinity of basic characters: it is productive in results, analytic and probative in method, and purposive throughout.

R. F. P.

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CHAPTER XI

INDUCTION

1. What Is Inductive Inference?

Knowledge grows by observation and inference. Inferences are conveniently divided into induction and deduction. Induction stands for all the direct studies of experience by which we build up piecemeal our funds of knowledge; deduction represents the processes of integrating and elaborating systems of knowledge and of applying them to particular problems. The one expresses the spirit of the explorer and the other that of the expositor. Claude Bernard declares, in his brilliant account of scientific method: "There are two forms of reasoning: the investigative or interrogative, which is employed by the man who does not know and wishes to learn; the demonstrative or assertory, which is used by the man who knows, or believes that he knows, and wishes to instruct others. The two forms belong to all possible sciences because there are in all sciences things which one does not know and others which one knows, or believes he knows." [1]

The general problem of induction is the original organization of experience. It is the search for new ideas and laws which will lift what is barely given in experience from its vague isolation into clear and comprehensive relations. *The products of induction are concepts of things and laws describing their activities.*

To appreciate the *problem of induction* we need to imagine ourselves divested of all the achieved conceptions and generalizations by which an educated person makes his way in the world. Then we should wander blindly and precariously in a multiverse where every occurrence would be new, nameless, and without meaning. Like the animals, we could not see beyond the present sensuous instant.

Inductions begin with the effort of the mind to trace for the first time lineaments of order amid the bewildering conglomeration of natural events. As soon as one discerns likeness or continuity between two appearances, he is freed somewhat from the prison of the present. He may notice, for example, that on several occasions dark clouds have been followed by rainstorms. In this synthetic act he has performed a simple induction: he has

[1] *Introduction à l'étude de la médecine expérimentale* (ed. 8), Paris, Delagrave, 1919, pp. 77–85. This book is a classic in logic for French university students; it was first published in 1865.

discovered an abiding law which binds together a few isolated facts. He has commenced a search for orderly connections which may lead to the ends of the universe. He is entering into more intimate and intelligent relations with his world. He has begun to organize experience. "The value of an inductive conclusion, as of any piece of knowledge, lies in the amount of reality which it enables us to grasp." [2]

We shall now examine inductive reasoning as a universal instrument of scientific investigation. It develops through the same stages as thinking or inference in general: (*a*) some problematic phenomenon is confronted, and (*b*) one proceeds to study the event and its context. The inquirer has in mind the question, *How think the fact?* How pass from sense stimulations to ideal insight? (*c*) The creative and crucial phase of induction consists in discovering a definite type or law of which the concrete phenomenon may be regarded as an exemplification. Whewell asserts, with striking clearness, that "induction is experience or observation consciously looked at in a general form." [3] (*d*) In the chapter on verification the last steps of induction will be analyzed: new instances are compared with old, and the generalization is finally extended from examined to unexamined instances. *Scientific induction, in short, is the inferential activity in which universal propositions or laws are discovered and certified by a direct and intensive examination of concrete facts.*

The phases of inductive procedure are illustrated by the effort to explain the destructive and dreadful phenomenon of lightning. Before the days of Benjamin Franklin scientists believed that thunder and lightning were produced by exploding gases of unknown constitution. In 1737 Franklin suggested that they are due to "the inflammable breath of the Pyrites, which is a subtle sulphur, and takes fire of itself." His notebook of November 7, 1749, records twelve specific respects in which lightning resembles electrical fluid. He then adds, "The electrical fluid is attracted by points. We do not know whether this property is in lightning. . . . Let the experiment be made." [4] He sent a sharp-pointed iron into the air during a thunderstorm and got electric sparks, a strong shock, and charged a Leyden jar. Thus he demonstrated that the thunderbolts of Zeus are of the same nature as the sparks from a cat's back or from an electrical machine. By a single principle he unified a multitude of diverse phenomena. Such an interpretation of particular facts by analysis, comparison, and generalization is characteristic of inductive thought.

[2] Bosanquet, Bernard, *Proceedings of the Aristotelian Society,* Vol. XI, 1910–1911, p. 39.

[3] Whewell, William, *Philosophy of Discovery,* London, Parker, 1860, p. 245.

[4] *The Works of Benjamin Franklin* (edited by Sparks), Chicago, Townsend MacCoun, 1882, Vol. V, pp. 350–351.

2. Types of Induction

All inductions may perhaps be classified under three general types: (a) concept-making induction; (b) enumerative induction, and (c) law-making induction. We shall now briefly describe and illustrate these more or less overlapping forms.

(*a*) Concept-Making Induction. — The mental activities by which our first ideas and rough generalizations are built up have been called "intuitive induction; . . . it is that species of generalization in which we intuite the truth of a universal proposition in the very act of intuiting the truth of a single instance." [5] For example, I cut an avocado for the first time and am surprised perhaps by its large seed. I add to my storehouse of experience a generalization to the effect that avocados have large pits, and I expect future instances of the fruit to manifest the same property. This example, however, is too sophisticated, for it rests upon the important presupposition that nature has a measure of dependable order. In the earliest stages of induction the observer is not yet aware of this postulate.

Better illustrations of primitive induction abound in the activities of children and intelligent animals. With them little is presupposed, and everything is new, vague, and shifting. As they constantly confront specific problems they occasionally catch a new idea. Thus Yerkes strove to teach an orang-outang to connect a small black signal with food. After staring long and stupidly, the ape suddenly mastered the problem by one right choice and never again made a mistake.[6] For him, of course, the crucial signal was physically a very insignificant spot in the total landscape, and he had no clear knowledge of the mechanism involved to indicate the importance of that particular spot. The child who says "I standed" has observed one or more instances of adding *ed* to a verb; he has inferred a general rule, and applied it again. His logic is flawless; the English language is illogical. He has found his way from the concrete to the ideal and back again. He has employed in a simple way the inductive-deductive procedure characteristic of advancing science.

In primitive induction, then, the mind is at work making ideas where accumulated clues are few, where there are no teachers or common traditions to be invoked. In the chapter on "Thinking" we saw how, by the remarkable process of abstraction, we gradually build out of our experience a host of usable conceptions. G. N. Lewis has suggested that, "A more or less complete list of our major and minor abstractions is furnished by any unabridged dictionary."

[5] Johnson, W. E., *Logic,* Cambridge University Press, 1924, Vol. II, p. 29.

[6] *Cf.* Köhler, W., "Intelligence of Apes," Ch. 8 in *Psychologies of 1925* (ed. 2), Worcester, Mass., Clark University, 1927, p. 149.

Concept-making induction is by no means confined to our first notions of the world. The rough conceptions of everyday life and early science may be taken up by the exact scientist, and shaped, polished, and perfected under the finer instruments of his analysis. Or, he may begin anew with original experience and slowly carve out of it the beautiful abstractions of mature science. The clear ideas which we now possess, for example, of the crystal, the atom, and the cell represent the culmination of years of laborious concept-making induction upon the part of multitudes of tireless investigators.

Every scientist and philosopher is expected to formulate, in the light of his richest knowledge and experience, the clearest possible conceptions of the objects and principles with which he chooses to deal. It is important to note that certainty increases as our clearness in the apprehension of a typical instance increases. The function of concept-making induction is to exhibit clearly how properties are constantly conjoined to constitute classes.

(*b*) Enumerative or Summary Induction. — A second kind of induction occurs when the scientist wishes a total numerical view of a certain class of facts. It has been called summary, perfect, or complete induction because the conclusion rests upon an *exhaustive enumeration of instances.* Jevons says, " An induction is called *perfect* when all the possible cases or instances to which the conclusion can refer, have been examined and enumerated in the premises." [7] The following assertions illustrate conclusions of this sort: all metals are conductors of electricity; every author of the Bible, except Luke, was a Hebrew; all of the planets and asteroids revolve about the sun from west to east; no two chemical elements have common lines in the spectrum.

Simple enumeration is the characteristic method of summary induction. The values and technique of enumeration will be explained further in the chapter on statistics. It is a slow and laborious process of building up a complete view of a group of homogeneous facts. Johnson explains Kepler's study of planetary orbits as a geometrical example of summary induction.[8] Kepler noted that every observed position of a certain planet corresponded with a position in an ellipse, and from this inferred that the planetary orbit as a whole is an ellipse. It is obvious that no such generalization could be derived from the most thorough analysis of a single observation. The conclusion results only as we can refer every observed position without exception to some point in a complete curve that is recognized as an ellipse.

While summary induction tells us much about the number of a class of things, it often tells us little about their nature or relations. It does not tell

[7] Jevons, W. S., *Elementary Lessons in Logic,* pp. 212–213; copyright 1919 by the Macmillan Company. Reprinted by permission.

[8] Johnson, *op. cit.,* Vol. II, pp. 199–200.

us, for example, why the planets move in the same direction, nor why elements have different spectra. It would be interesting to know that a surgeon had succeeded in ninety-five operations out of a hundred, but progress in knowledge would come if the reasons for his five failures could be determined. In ascertaining the necessary causes, one employs a third type of induction which we shall now describe.

(*c*) LAW-MAKING INDUCTION AND THE POSTULATES OF SCIENCE. — Law-making induction is one of the most important and characteristic forms of scientific reasoning. It aims at ascertaining the laws which operate among phenomena. A good example of it is found in the well-known search for the cause of yellow fever. We shall suppose that the important observation has already been made that this disease is somehow connected with certain bacteria-carrying mosquitoes. The problem is to determine whether these insects are the necessary cause of the terrible malady.

The solution of this problem falls into three logical stages. First of all, we assume the uniformity of nature in the specific form that all men who are bitten by this mosquito under similar physical conditions will react in similar ways. Without this general assumption the investigators would hardly have considered the dangerous experiment with yellow fever worth the risk of several human lives. Next, the experimental conditions for testing the hypothesis are carefully planned. One group of men volunteer to let the poisonous mosquitoes bite them. A second group live under the same conditions as the first except that they are protected from the mosquitoes by fine screens. The first group contract the disease. We conclude, in the third place, that this particular mosquito is the true cause of the fever. We set up the universal law that if any other human being were so infected, he would suffer the same dreadful consequences.

Law-making inference may be formulated in two premises and a conclusion. The major premise is a postulate concerning the order of nature; the minor premise is a fact or group of facts carefully derived from experience. From these premises we draw a conclusion which is a specification of the first premise and a generalization of the second. Johnson has called this kind of reasoning " demonstrative induction " because it leads to clear and cogent conclusions.[9]

Inductive investigation is sustained and stimulated by a small number of great germinal ideas called the postulates of science. These ideas express the cumulative experience of mankind to the effect that nature is a cosmos and not a chaos. Faith in the order of nature often enables the scientist to pass with confidence from the intensive study of a small number of instances to a universal law. The chief postulates of science are the following three: —

[9] *Op. cit.*, Ch. 10.

1. *The postulate of the uniformity of nature is the conception that similar causes or grounds acting under similar circumstances always determine similar consequences.* From like seeds, chemicals, machines, or geological agents, like results may be expected under like conditions. If events were capricious and desultory, if we lived in a chronic chaos, we could learn nothing from experience, general laws and predictions would be impossible, and we could exercise no control over phenomena.

2. *The principle of sufficient causation declares that everything which exists has a sufficient cause; in other words, every phenomenon is determined in a definite and orderly way.* The belief that reality is coherent and intelligible is perhaps the most fundamental assumption of all sanity, science, and philosophy. It is at the same time the grandest of all inductions.

A cause in science means any phenomenon which fulfils a necessary place in a sequence of natural events. Causality is determination according to law. Necessity means that the effect cannot occur or exist without the cause. An effect, however, often requires more than one antecedent. Thus the growth of a plant, the trajectory of a shell, or the rise in the price of pig iron, depends upon many factors. *The complete scientific cause for any phenomenon is the set of proximate factors that are sufficient and indispensable for its production.*

3. *The postulate of limited conditions states that any event can be sufficiently explained for scientific purposes by reference to a limited context or assemblage of factors.* A botanist must include light and water as essentials of growing plants, but he is not required to explain light, the solar system, or the origin of oceans. The scientist, unlike the philosopher, need not consider the complex totality of human and cosmic factors which may condition phenomena.

3. Mill's Methods of Causal Determination

The main business of science is to discover and verify causal laws. The most important logical aids in this task are called Mill's methods. The basic principles of these methods were clearly stated in 1620 by Francis Bacon, the most notable modern apologist of inductive investigation. He declares, " Induction itself is brought into action [when] on an individual review of all the instances a nature is to be found such as is always to be present and absent with the given nature, [and] to increase and decrease with it." [10] Nearly a century ago two other Englishmen, Sir John Herschel and William Whewell, richly illustrated the inductive methods of science in their works and influenced John Stuart Mill (English, 1806–1873) in writing his *System of Logic* (1843). This great work contains the most

[10] Bacon, Francis, *Novum Organum,* Vol. II, aph. XV; see also aph. IV and XII.

original and elaborate exposition of inductive proof made up to that time. Mill's canons, in spite of their many imperfections, continue today to be indispensable rules of scientific inquiry.

(*a*) THE METHOD OF AGREEMENT. — The first study of a phenomenon *P* is often bewildering because it occurs amid a crowd of circumstances and the observer has no initial way of distinguishing between adventitious and crucial conditions. He can only suppose that *P* has many properties and relations: *P* is *A* or *B* or *C* or . . . He must, therefore, carefully analyze, compare, and weigh many instances. *By instance is meant any space-time complex which can be observed and analyzed into several components.*

But if some time the observer notices an instance in which *P* and *A* occur together, he will seize upon this first glimmer of order and try to test its truth. A backward survey of science shows many original observations of concurring phenomena which proved fertile. Arago noticed that a magnet suspended over a rotating copper disc tends to follow the movement of the disc; the electric dynamo eventually resulted. An English farmer observed that wheat rust was most abundant on the leeward side of barberry bushes which were infected with rust; in consequence the cycle of wheat rust was discovered and brought under control.

The observer may note, however, that not every instance of *A* is *P*. He proceeds then to examine other instances of *A* to ascertain whether they are also *P*. If he finds that *P* and *A* recur together in spite of other variations, he suspects that they are bound by a natural law. His reasoning may be formulated thus:

> Instances 1, 2, and 3 are *P;*
> They are also *A;*
> Therefore, perhaps every *P* is *A*.

This conclusion has been reached by the method of agreement, so called because the observed instances agree in the coincidence of certain properties. It might also be well named the method of similarities or the method of compresence.

The rule or canon of the method of agreement is that two phenomena are probably connected by law if they constantly occur together even when other circumstances differ. In this way it has been shown, for instance, that hot sponges or cloths hasten the coagulation of blood while cold applications retard or prevent it.

On the other hand, *if one of two phenomena sometimes occurs in the absence of the other, we infer that they are accidentally and not lawfully connected.* For example, it was once supposed that the heat necessary to change the temperature of different bodies was in proportion to their weights. Joseph Black in 1760 proved, however, that no such correlation

exists. He found that quicksilver, although thirteen times as dense as water, produced less effect in heating than an equal amount of water.

We have stated and illustrated a rule which may be called *the method of disagreement* because it is a corollary of the method of agreement. Evidently the absence of a circumstance is significant only if we had anticipated its presence. The positive method is a guide which saves us from endless wandering in realms of impertinence. The method of disagreement provides a natural *criterion of irrelevance: two phenomena are irrelevant if one can function in the absence of the other.* As we are learning what is unessential we learn also what is essential. One method helps us in finding characters that belong together; the other, in eliminating spasmodic or incidental circumstances.

The first chapters of any science teach us how important but how slow may be the weeding out of disturbing non-essentials. Thus, when the marvelous Leyden jar was discovered, everyone wanted to know the precise cause of the mysterious electric shocks which it produced. Was this cause the human body, the water in the vessel, the material, temperature, or arrangement of the parts of the jar, or some other undetected factor or combination of factors? The true cause was discovered only after many false guesses had been rejected. Exceptions brought to light by the incisive method of disagreement have destroyed many a cherished hypothesis. If, however, every examined *P* is *A* and no examined *P* is *not-A,* we conclude with considerable probability that every *P* is *A*. *Constant compresence indicates causal connection.*

Reasoning by the method of agreement is very susceptible to several fallacies to be described below. It yields generalizations which have only a relatively low degree of probability. These conclusions must be tested wherever possible by the surer method of difference. Contradictory and variant instances need to be impartially sought and critically examined.

(*b*) The Method of Difference. — The method of difference is undoubtedly the most important rule for discovering and proving causal connection. It may equally well be called the method of variation. It is a direct application of the principle of sufficient reason: "There is no difference without a reason." It consists in discovering or producing a negative instance, that is to say, an instance in which the phenomenon under investigation is absent. In this way it carries one step further the method of agreement. One of the causal factors suggested by the method of agreement is experimentally removed to see what will happen. The result may be an unexpected change in the total situation.

The canon of the method of difference may be stated thus: two factors, A and B, in a complex situation are causally connected if the elimination of one entails the disappearance of the other, or, more generally, if a change

in one factor entails a change in the other. For example, if a certain culture of bacteria dies soon after it is brought into sunlight, we infer that sunlight is a lethal agent in relation to those bacteria.

Such purposive variation is the ruling principle of experimental procedure. It is perfectly adapted to studying the ever changing world in which we live. One's skill as an experimenter is measured by one's ingenuity in devising means for varying one circumstance of a phenomenon at a time. The apparatus of Millikan for observing moving atoms may be cited as a brilliant example of inventiveness in bringing elusive phenomena under controlled observation.

The method of variation is very extensively employed in everyday life and science. Let us note some examples. Daniel employed it when he requested that he and his three companions be permitted to eat pulse and water instead of the food and wine provided by Nebuchadrezzar. "And at the end of ten days their countenances appeared fairer and fatter in flesh than all the children which did eat the portion of the king's meat." [11] Dr. A. do Amaral of Butantan, Brazil, has recently investigated the supposed efficacy of alcohol as a remedy for snake bites. He injected dogs with deadly cobra venom and then gave alcohol to half the animals. The drunken dogs invariably died long before the others.

In order to determine the relation between electrical and chemical action, Faraday studied the electrolysis of dilute sulphuric acid under different conditions; he varied the magnitude of the current, the size of the electrodes, and the strength of the acid. He concluded that the quantity of the gas evolved depended only on the quantity of electricity which passed through the circuit. Such variations enable the investigator to define the cause or correlation present with a high degree of certitude. *Any factor which invariably disappears with a given phenomenon and always returns with it is causally connected with that phenomenon.*

The methods of agreement and of difference are fundamental and complementary. They involve, as Bowne suggests, "the gist of experience and the sum of inductive logic." According to the first, agreement in the cause will entail agreement in the effect. When the two instances *ABCDE* and *ABFGH* occur in turn, we infer that factors *A* and *B* are related in some way. According to the canon of difference, a difference in the cause will entail a difference in the effect. If, starting with *ABCDE,* we eliminate *A* and get *CDEFG,* we infer *A* is the cause of *B*. Thus the two methods yield mutual support. We infer necessary connection when phenomena vary together in the midst of constants, or conversely when they remain in agreement in the midst of variables. In brief, *constant compresence and constant covariation connote necessary connection.* In applying the principle of

[11] *Daniel,* Ch. I.

agreement, we seek instances which vary as much as possible outside of the constant characters under investigation; in the method of difference we want cases to agree as much as possible outside of the factor that is being varied.

The method of difference, like that of agreement, has its negative aspect, its proper criterion of irrelevance. It is obvious that *two phenomena are not causally connected if a change in one produces no change in the other.* Thus Claude Bernard showed that the sugar content of blood does not vary with alimentation. Creighton declares, " That is not the cause of a phenomenon which varies when it is constant, or is constant when it varies, or varies in no proportionate manner with it." [12]

A classical demonstration of irrelevance is found in Galileo's proof that the variation in the weight of a body does not effect the rate of its fall, as Aristotle had affirmed. One morning he dropped from the top of the leaning tower of Pisa a one-pound shot and a hundred-pound shot. The assembled multitudes saw the balls start together and strike the ground together. (Some returned to their Aristotle unconvinced by the plain testimony of their senses.) What can be eliminated, then, without affecting the phenomenon is causally irrelevant; what cannot be eliminated has a causal or other necessary connection with the phenomenon in question.

(*c*) Extensions of the Methods of Agreement and Difference. — The other three methods of Mill are extensions or corollaries of the two basic methods already described.

1. Let us examine first what he called *the joint method of agreement and difference.* This name is unfortunate because it falsely suggests that this principle incorporates the experimental procedure and the certainty which characterize the method of difference. Mill's other name, the double method of agreement, is less misleading but is not in common use. The joint method is in fact only slightly surer than the somewhat uncertain method of agreement.

It sometimes happens that an investigator cannot experimentally remove or vary one circumstance at a time as required by the method of difference. Under these conditions he does his best to secure numerous instances in which the phenomenon considered is naturally present, and also instances, as similar as possible, in which it is absent. Then, by analysis and comprehensive comparison, he endeavors to reach some estimate as to what causal relations are operative. In this way any social institution, such as the jury system, the moving picture, or certain traffic regulations, might be investigated.

The rule of the joint method may be stated thus: if two phenomena are

[12] Creighton, J. E., *An Introductory Logic* (ed. 4), p. 238; copyright 1921 by the Macmillan Company. Reprinted by permission.

naturally present and absent together in a wide range of varying circumstances, it is probable that they are causally connected. The chief services of the joint method consist in bringing to light plural causes and in uncovering irrelevant circumstances.

2. Mill's *method of concomitant variations* is an important extension or modification of his method of difference. It may also be named *the method of covariation.* Instead of removing a phenomenon, as in difference, we study the varying degrees of its effect in operation. Mill's formulation of this method is as follows: "Whatever phenomenon varies in any manner whenever another phenomenon varies in some particular manner is either a cause or an effect of that phenomenon, or is connected with it through some fact of causation." Bacon very well stated the principle in question as follows: "No nature can be considered a real form which does not uniformly diminish and increase with the given nature." [13]

A simple example of covariation is found in the study of a music box in a bell jar. As the air is gradually pumped out, the sound of the music becomes less and less audible. We conclude that sound is not transmitted in a vacuum. An inverse correlation exists between the volume and the pressure of a gas, or between the supply and the price of a commodity. In general, we infer that two *series* are causally connected if determinate changes in one correspond in some regular way with determinate changes in the other.

3. The fifth and last method of Mill is called *the method of residues.* He stated it as follows: "Subduct from any phenomenon such part as is known by previous inductions to be the effect of certain antecedents, and the residue of the phenomenon is the effect of the remaining antecedents." The value of this method is narrowly limited to pointing the way occasionally to the discovery of causal connections. It suggests that certain causes must be operative, but gives no indication concerning their nature. Strictly, it is a form of deduction and will be explained further in the following chapter.

A notable example of reasoning by the method of residues is found in the discovery of radium. In 1898 Mme. Curie was studying the radioactivity of uranium when she noticed that certain varieties which naturally occur in nature, notably pitchblende, showed radioactive effects several times greater than her previous experiments had led her to expect. She inferred that these peculiar specimens must contain an unknown substance. As a result of long and tedious labor she and her husband were able to isolate from a ton of ore about one-fifth of a gram of a heavy substance which was about two million times as radioactive as uranium. They named the new substance radium.

We have now completed our review of Mill's methods. We may roughly

[13] *Novum Organum,* Vol. II, aph. XIII; *cf.* aph. XV and XVI.

epitomize them thus: *we infer that phenomena are causally connected when they are present or absent together or when they vary together.* Macaulay's comments (in his essay, *Lord Bacon*) on Baconian method have been summarized thus: The man who infers that mince pies have disagreed with him because he was ill when he ate them, well when he ate them not, most ill when he ate most, and least ill when he ate least, has employed unconsciously but sufficiently all the tables of the *Novum Organum.*

4. The Fallacies of Induction

We have seen how the method of difference or variation is the fundamental method of experimental science. It applies only where *elementary* causal factors can be altered *one at a time.* When one circumstance which is supposed to be connected with a given phenomenon *P* is varied, any one of the three following results is possible: (1) *P* changes; (2) *P* does not change; (3) *P* sometimes changes and sometimes does not. We pointed out above the evident interpretation of the first two cases.

The third case presents much more serious difficulties. It means that an undetected causal factor is operative in some instances and not in others. Intermittent results indicate that a situation we have taken to be simple is really complex and in need of further analysis.

(*a*) The Fallacy of Partial Cause.—Under these conditions it is easy to fall into the *fallacy of incomplete or partial cause.* It consists in referring an effect to one cause when several are actually operative. Lavoisier, for example, regarded lime as an element because it had not been decomposed up to his time. The fallacy of partial cause is also called *the fallacy of false simplicity.* It is common in explaining such complex effects as wealth, poverty, personal charm, or success.

Exceptions or irregularities that are not illusory point to an undiscovered cause or law. It was observed, for instance, that the freezing point of benzine is variable, even when pressure, temperature, and all other known factors were kept constant. Then it was suggested that, since air is soluble in this liquid, perhaps air pressure affected its freezing point. Experimental analysis showed a difference of 0.031 degrees in the freezing points of air-free and air-saturated benzine. It was also found that dissolved air is a determining factor in the melting point of other organic compounds.

Irregularities may be due not only to a complex cause but to a combination of known causes. We may have determined all the factors, *ABCDE,* in a situation, but we may have overlooked the fact that the phenomenon is produced only if *D* and *E* are combined in a certain way. Although the molecule of ozone contains nothing but oxygen, the atoms are so combined that ozone has an odor as well as sterilizing and explosive properties which

oxygen lacks. The investigator, therefore, must be on his guard for novelties that result from the peculiar *combination* of familiar factors.

(*b*) The Fallacy of Irrelevant or False Cause. — A very common error, especially in employing the method of agreement, consists in mistaking the casual for the causal, in taking the mere sequence or coincidence of phenomena for necessary connection. It is called *the fallacy of irrelevant or false cause;* also, *post hoc ergo propter hoc.* For example, certain insects, when suddenly uncovered, run for shelter, not, as we might at first suppose, because of light, but for want of contact with something, as the substitution of a glass covering would readily prove.

A person of sluggish or uncritical mind readily jumps to a conclusion from a single event or association which chances to strike his imagination or interest. In this way charms, amulets, fetishes, unlucky days, quack medicines, and a host of signs and prepossessions have come to be cherished. The destructive criterion of the method of disagreement is not applied. Negative instances are neglected because they do not fit one's first impressions or one's wishes. *By selecting one's data and ignoring enough facts, one can prove anything.* The careful thinker will beware of lazily mistaking the force of habit for the cogency of thought, or subjective impressions for objective necessity. He will remember that nonsense syllables can be as firmly associated as the profoundest words of wisdom.

An important species of false cause may be called *the fallacy of abstraction. It consists in mistaking abstract concepts for causal entities.* Since most nouns stand for existing objects, a careless thinker easily falls into the error of supposing that all do. An example of this fallacy is found in the superstition that fortune or fate exerts causal efficacy in bringing misfortunes or happiness to men. The hypostatizing of such abstract conceptions as public opinion, the state, justice, or force, and the treatment of them as dynamic agencies, are examples of this fallacy.

(*c*) Other Types of Inductive Fallacies. — Another inductive mistake has been called *the fallacy of circular cause.* If two factors exert a mutual or coöperative influence, we err in referring the total effect to either alone. We should commit this fallacy if we said we run because we are afraid, for the truth, according to the James-Lange theory of emotion, is that the running itself, once started, promotes the emotion of fear. Similarly, popular taste both shapes and is shaped by the music, moving pictures, dramas, books, and fashions that are offered to the public.

Again, we may sometimes fail to obtain the fair samples requisite for a generalization. A conclusion from instances having exceptional or accidental properties is likely to be false. A mistake of this kind is called a *fallacy of accident.* It consists in mistaking the extraordinary for the usual or uniform, or in taking some proposition as true absolutely when it is

valid only under certain restrictions or limitations. It is very unlikely that the cluster of grapes which the spies brought back to Moses from Canaan was a fair specimen of the fruit of the promised land. Again, a false estimate of a foreign people is readily formed if we happen to know representatives of only a special type, such as selected students, wealthy travellers, or untutored laborers.

False analogy belongs in the list of inductive fallacies. It will be explained in the chapter on discovery.

In using the method of difference, we need to be on our guard against factors that prevent the appearance of an effect which we expect normally to happen. Thus wetness may prevent the explosion of gunpowder under the usual conditions of explosion.

In applying the method of concomitant variations, one may mistake the effects of a common cause for cause and effect (*fallacy of covariation*). Thus, while the preference of students for certain tunes and their being played on the college chimes may exert a mutual influence, both these facts may be largely the common result of a third fact; namely, the relative simplicity of the tunes concerned. We may fall into error also by continuing a curve of covariation beyond observable limits. For instance, we may have complete knowledge of the variations of a certain chemical substance through all the temperatures and pressures which can be produced in the laboratory. We can only guess at its behavior at absolute zero or under the immense temperatures and pressures that may operate in the interior of the earth or of a star.

The fallacy of numbers consists of falsely assuming that a proposition is true because a large number or a majority of people accept it. This widespread popular superstition will be illustrated in the following section.

All of the fallacies illustrated above may be subsumed under the head of *hasty or illicit generalization.* They are perhaps the most prevalent of all logical vices.

5. Why Multiply Instances in Induction?

In general, inductions are more surely established by the thorough analysis of a few instances than by the cursory examination of many. Nevertheless, we cannot easily dismiss the feeling that accumulating numbers somehow influence the probability of an assertion. The democratic procedure of deciding issues by majorities suggests that the counting of heads is a criterion of truth. A recent advertisement declares in bold type, " 350,000 people can't be wrong." Legislative bodies have presumed to judge the biological theory of evolution by counting ballots, and some ecclesiastical assemblies promulgate truth on the authority of a majority. Yet the weight

of evidence favors the proposition that, outside of statistical inquiries, *the number of votes or of instances has little to do with the truth of an assertion.* We shall show how the reason for multiplying instances differs in each of the three types of induction.

(*a*) Primitive induction, as we have seen, is the effort to organize a fresh field about which we know little. Obscure and complex situations exist, and the realm of the relevant is ill defined. Such enigmatic situations abound in the early study of electricity, light, combustion, weather, oil deposits, and a host of other perplexing phenomena. Under these indeterminate conditions, generalization from a single instance, even if possible, is precarious, illicit, and stupid. We need to canvass a large number of facts to get our bearings and to learn how to separate the relevant from the irrelevant. Charles Darwin rightly said, " I must begin with a good body of facts."

What does it mean to get our bearings in a new field of study? It means attaining as soon as possible a clear conception of relevant phenomena. *We have a clear idea of anything when we grasp* (*1*) *its organic relations* (*likeness, difference, causality, etc.*) *with kindred phenomena and* (*2*) *its intrinsic properties and activities. Instances need to be multiplied to help us get clear ideas of things.*

While our knowledge is adolescent, the accumulation of fair samples is the best available substitute for the clear insight we are seeking. *Fair samples are assorted cases of a phenomenon selected at random from widely different parts of the field under investigation.* By comparing many such instances we may come to discern what is normal, crucial, or uniform, as well as what is anomalous, non-essential, or accidental.

New instances are contributory when they reveal some novel character or relation of the facts being studied. When new instances cease to do this, multiplication of them becomes worthless and uninteresting. Thus, if a chemist examines samples of iron from widely separated regions of the earth, from the chief geological formations, and from various meteors, and if he finds that their atomic weights are constant within the limits of a few units per million, the study of further samples is of slight value.

In primitive induction, therefore, *the value of instances is not in proportion to their number but in proportion to their significant variety.* We multiply instances here only to obtain maximum variety and clear ideas. To evaluate repetitions is far more important than to count them.

(*b*) In enumerative or summary induction, numbers are of primary importance because this kind of induction consists in complete enumeration. It concerns problems that can be solved only by counting numerous cases. If we wish to know the rate of births, deaths, or marriages in a city, the health of school children or the extent of crime, the study of a few

individuals would not serve our purpose. Under these circumstances a multitude of cases, if not all, must be considered.

(*c*) *In the law-making induction of exact science, only a relatively few instances are needed to establish a generalization.* This sort of induction takes place against an orderly background of knowledge and assumption. Against such a background the clear comprehension of a single phenomenon may contribute more to clearness and truth than ten thousand additional instances.

Where we are confident that great homogeneity exists among facts, as in the study of diphtheria, sunlight, or human cadavers, we may determine their true nature by an examination of a few typical instances in all their bearings, sometimes of a single fair sample. The analysis of one carefully selected thimbleful of water may reveal, with a high degree of certainty, the constitution of the seven seas. It is obvious that we might see a thousand fires without discovering that combustion is oxidation, but having made that discovery in one case, the observation of a thousand other fires might not increase a whit our knowledge of combustion. Thus, in a developed field of science an alert observer may sometimes derive a far-reaching generalization from the thorough inspection of a few crucial cases.

In law-making induction, then, instances are multiplied for the following reasons: (1) to compare modified instances produced according to the method of experimental variation; (2) to guarantee representativeness in specimens; and (3) to check against personal errors in observation. A variety of cases provides materials for comparative observations at successive times by different persons under varying conditions so as to eliminate mistakes of perception, memory, or measurement.

To the question, *Why multiply instances in induction? we may, then, reply summarily as follows: (1) in primitive induction, to obtain fair samples and clarify the field; (2) in summary induction, to complete the enumeration; (3) in law-making induction, to vary and verify our observations.* Certitude lies, not in the number nor the frequency of instances, but in their nature, and that nature we learn by an intensive study of how the phenomenon actually functions in its natural context.

Our exposition of the principles of induction is now finished. We have seen how *induction is a systematic search for the laws of order in experience.* To phenomena that at first appear confused and multifarious, inductive study gives a measure of clearness, coherence, and simplicity, and binds the perishing particulars of experience into abiding concepts, laws, and knowledge systems.

R. F. P.

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CHAPTER XII

DEDUCTION

1. The General Nature of Deduction

Deductive inference makes possible an enormous economy in dealing with recurring problems. Having defined a class of facts, we are saved the tedium of treating every new instance with the same thoroughness as the original instances. As soon as a fresh fact gives a hint that it belongs to a familiar class, we immediately assign to it the universal characteristics of that class. Such reasoning is the essence of deduction. By it we put to use the countless concepts, rules, recipes, and formulas which inductive processes accumulate.

Deduction and induction solve different problems. We think inductively when we strive to construct the law that governs concrete and fragmentary data. We think deductively when we seek, among achieved principles or systems, one that will resolve a particular problem which confronts us. Thus, induction is generalizing thought; deduction is particularizing and applicatory. Medical investigators, for example, may ascertain by hard inductive study and experimentation the effective remedies for specific diseases. Then, when a sick man comes to a practitioner who knows these remedies, the latter proceeds deductively; he first diagnoses and classifies the disease, and then makes the proper prescription.

Deductive reasoning, then, presupposes developed knowledge or assumptions as working materials. It plays an ever larger part as a field of knowledge becomes more definite and systematic. The innumerable deductions that abound in daily life and science fall into a few typical forms. This chapter is devoted to a study of these types.

Deduction presupposes also the general conditions of all thought. These conditions include a thinking self, an intelligible world of connected objects, and a few laws or rules which the thinker finds necessary to impose upon himself as conditions for attaining truth. Three basic laws of thought follow; others will appear later.

(*a*) *The law of identity demands that the meaning of terms be relatively fixed and consistently used.* If terms acquired an entirely new significance with every occurrence, thinking would vanish in a chaos and knowledge would cease to exist. Violations of the law of identity give rise to the fallacies of ambiguity and equivocation.

(*b*) *The law of contradiction forbids us both to assert and to deny the same character of an existing object.* Contradiction appears when different terms claim to occupy the same place. The law warns us against confusing things that are naturally different. To be consistent is the golden rule of logic.

(*c*) The law of contradiction declares that *x* and *not-x* cannot both be true. *The law of excluded middle asserts that* x *and* not-x *cannot both be false; either* x *or* not-x *is true.* If two incompatibles exhaust a universe of objects and one is false, the other must be true.

2. Nature and Kinds of Simple Propositions

Deductive reasoning consists in the accurate interpretation and combination of accepted propositions according to the laws and rules of thinking. *A proposition is a verbal enunciation of a judgment.* It is a judgment articulated in the more or less fixed, public, and precarious form of words. Propositions are either simple or compound. We shall first analyze some simple propositions.

The simple proposition is the characterization of a subject *S* by a predicate *P* as described in the chapter on judgment. *P* determines *S* and *S* limits *P*. *S* stands for any object of thought whatever and *P* symbolizes any relevant property. Any word or combination of words that can serve as *S* or *P* in a proposition is called a *term.* The existence of this unique " tie " between *S* and *P* is formally signalized by the insertion of a form of the verb *to be* called the *copula.* Simple propositions are also called categorical because *P* is asserted as really or unconditionally characterizing *S*. *Categorical propositions* are essentially declarative sentences expressed in certain typical forms.

Of the several types of categorical propositions, four have been thoroughly studied in traditional logic. In the field of perception and history propositions of the form, *This S is P,* are common; for example, *This snowflake is an hexagonal crystal;* or, *Aristotle is the greatest thinker of all time.* These propositions are called *singular* because each concerns one concrete existent. By induction we pass to statements of the form: *Every S is P;* for example, *Every snowflake is an hexagonal crystal;* or, *All solidified water is crystalline.* The last two propositions are called *universal* because the predicate refers to all members of the subject class. The singular proposition sometimes may be treated as a universal, since its predicate concerns the totality (namely, one) of its subject. It cannot be used, however, as the major premise in a syllogism.

When a character is asserted of a part of a class, the proposition is called *particular* (Latin, *particula,* part); for example, *Some pieces of*

carbon are diamonds; Many trees are evergreen. Some represents a reference of indefinite extension; it means *at least one and perhaps all;* it reflects preliminary and indeterminate investigation. Universal and particular propositions are conveniently symbolized respectively by *A* and *I* (Latin, *affirmo,* I affirm).

Universal and particular propositions are said to differ in *quantity;* propositions also differ in quality; namely, they are either affirmative or negative. Some negative propositions are particular, as, *Some shrubs are not deciduous.* Other negatives are universal, as, *No fungi contain chlorophyl.* The conventional signs of universal and particular negatives are *E* and *O* (Latin, *nego,* I deny). Since the proposition, *All S is not P,* is ambiguous in modern languages, the universal must be expressed in the form, *No S is P.*

Every categorical proposition has both quantity and quality. Since there are two kinds of each, there are four types of simple propositions, as follows:

		Quality	
		Affirmative	Negative
Quantity	Universal:	*A*: *All S is P*	*E*: *No S is P*
	Particular:	*I*: *Some S is P*	*O*: *Some S is not P*

Each has four explicit components: two elements of form (sign of quantity and copula) and two of matter (*S* and *P*). We shall see in a moment how a fifth factor is assumed: the quantity of *P*. The student will find it convenient to remember distinctly the meanings of the above symbols.

In the study of propositions it is important to note whether the reference to a term is partial or complete. *A term is said to be distributed when reference is made to all of its members; it is undistributed when reference is made to a part of them. No* and *all,* and their equivalents, mark distributed terms. Partial reference is indicated by such words as *some, few, most, many.* The predicates of propositions have no explicit signs of quantity; these signs are understood or assumed. The following rule states the distribution of all eight terms in the four typical propositions: *The subjects of universals and the predicates of negatives are distributed; other terms are undistributed.* The rest of the categorical syllogism will be easy for the student who has mastered distribution and learned this rule. A hint to the wise is sufficient.

3. The Interpretation of Propositions

The interpretation of a proposition consists in bringing to light its unseen meanings. The simple transformations of conversion and obversion,

which we shall examine in a moment, aid us in seeing a proposition from new points of view. They are called *immediate inferences* because they lead to conclusions directly and do not depend upon any second premise. The logician leaves to literary interpreters the study of the delicate shades of meaning which context and polished diction may impart to an assertion.

Propositions which are ambiguous in their essential structure are called *amphibolies.* They abound in oracles, newspaper advertisements, and freshman themes. A notable example of amphiboly is found in the famous Nicene Creed, where the words, " by whom all things were made," may refer either to the Father or to the Son.

Conversion is a change in the order of terms in a proposition. The converse of the relation of wife to husband is the relation of husband to wife. While every relation has a converse, a simple interchange of subject and predicate sometimes yields invalid results. *The important rule of conversion is that no undistributed term may become distributed.* The members of an equation obviously may be interchanged at will. This is an important change in mathematical reasoning. It is clear also that if *No S is P,* then *No P is S,* and that if *Some S is P, Some P is S. If no criminals are voters, no voters are criminals. If some snakes are poisonous, some poisonous things are snakes.* The relations so far considered are called symmetrical, or reversible, and are *converted simply.*

Propositions *A* and *O* are not symmetrical, and require special treatment. The assertion that *All S is P* does not guarantee that *All P is S.* It does imply, however, that *Some P is S,* provided *S* represents real objects. This is called *conversion by limitation.* The conversion of *A* without reducing its quantity is the important and common *fallacy of conversion.*

It is often said that proposition *O* cannot be converted without violating the rule of conversion. It is absurd, for example, to assert that *Some monks are not men* because *Some men are not monks. O* does have a converse, although it is insignificant and awkward to state. It is the following *E* proposition: *" No P is one of those S's which make up the some S which are not P."* [1]

The converses of spatial, temporal, and quantitative relations offer little difficulty. For example, from *All S's are to the left of, before, or greater than P,* we can infer that *All P's are to the right of, after, or less than P.*

Obversion consists in changing the quality of a proposition. Thus Moffat has altered *Romans* XII: 9 from " Let love be without dissimulation," to " Let your love be a real thing." Again, Aristotle inferred that

[1] Roelofs, H. D., " The Distribution of Terms," *Mind,* 1927, p. 289.

since the earliest philosophers philosophized in order to escape from ignorance, they were evidently pursuing science in order to gain knowledge.

Obversion is based on the principle of double negation. Since a proposition has only one negation, to deny that amounts to affirming the proposition. If, for example, the world of color is thought of as divided into red and not-red, then to assign an object to the not-red field is equivalent to denying that it is red.

The rule for obverting any proposition is: *Displace the predicate by its contradictory and change the quality of the proposition.* Thus, *Every phenomenon has a cause* becomes *Nothing happens without a cause.* Special care needs to be taken to obtain the true contradictory of the original. For example, the contradictory of *moral,* taken in a broad sense, is not *immoral,* but *non-moral.*

There are many other varieties of immediate inference. Valid propositions which are different may often be obtained by alternately obverting and converting a given proposition. Other immediate inferences may be drawn as indicated in the table in the following section.

4. The Opposition of Propositions

Each of the typical categorical propositions, *A, E, I,* and *O,* may be compared with the other three. The comparison of propositions which have the same *S* and *P* but different forms is called the opposition of propositions. The kinds of opposition are graphically represented in the square of opposition (Figure 18).

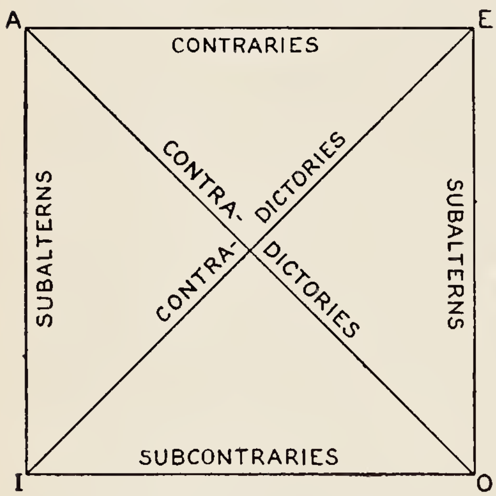

Fig. 18. Square of Opposition

The seven possible relations between propositions are summarized in Table VI.[2] Some of these relations will be more fully explained in the pages that follow. (We shall use p and q to symbolize propositions, and $\bar{p}$ and $\bar{q}$ to represent their negations — read: *not-p,* or p false, etc.) The table presents definite conceptions of consistency and inconsistency by exhibiting three forms of each. The relations are arranged from the highest degree of consistency to the extreme limit of disagreement. Propositions are called contrary or inconsistent when they represent oppositions between which

[2] *Cf.* Johnson, W. E., *Logic,* Vol. I, p. 49.

a third possibility exists. Thus, water may be neither hot nor cold, but lukewarm. A geometrical figure could not be both a circle and a square; it might be neither. Again, some figures may be circles and some squares. Between contradictories no such third possibility exists. The contradictory of *This figure is a circle* is *This figure is not a circle.* It is assumed that in universal propositions the subject class exists; otherwise no true particulars could be inferred from them.

TABLE VI. PROPOSITIONAL RELATIONS

DIFFERENCE IN RESPECT TO:	KIND OF RELATION	TRUTH STATUS	SYMBOLIC REPRESENTATION
Neither quantity nor quality	1. *Equivalence:* p implies and is implied by q.	Both are true, if either is true.	*A* to *A* *O* to *O* etc.
Quantity only	*Subalternation:* 2. Superaltern relation: p implies but is not implied by q.	Both may be true or both may be false. If a universal is false, its subaltern is indeterminate.	*A* to *I* *E* to *O*
	3. Subaltern relation: p is implied by but does not imply q.	If a particular is false, its superaltern is false.	*I* to *A* *O* to *E*
Universe of discourse	4. *Independence:* p has none of the other six relations to q; for example, *St. Luke was a Greek* and *Mercury is the smallest planet.*		
Quality only	*Inconsistency or contrariety:* 5. Subcontrary relation (between particulars): p is alternative but not disjunctive to q.	Both can be true; both cannot be false. If either is false, the other is true.	*I* to *O* *O* to *I*
	6. Contrary relation (between universals): p is disjunctive but not alternative to q.	Both cannot be true; both can be false. If either is true, the other is false.	*A* to *E* *E* to *A*
Both quantity and quality	7. *Contradiction or negation:* p is both alternative and disjunctive to q.	Both cannot be true; both cannot be false. If either is true, the other is false. If either is false, the other is true.	*A* to *O* *E* to *I*

5. Conjunctive Propositions and Reasoning

We have seen how a simple proposition assigns a predicate to a subject. A compound proposition relates simple propositions in some way. We shall consider *three important kinds of compound propositions: conjunctive, implicative or hypothetical, and disjunctive propositions.* We shall study their use as premises in valid deduction.

A *conjunctive proposition* asserts simultaneously two, or more, simple propositions connected by the conjunction *and;* for example, *Mr. A is a physician and (Mr. A is) a senator; 0° is the freezing point and the melting point of water.* " And " is here to be taken in a combinatory, and not in a distributive or enumerative sense. A conjunctive proposition is to be considered to be true or false as a single whole, for one of its components may occasionally be false, as when a poor newsboy declared, " Mr. Rockefeller and I are worth millions."

Conjunctive operations are important in arranging and combining items of knowledge. The rules of conjunction are obvious. They may be epitomized in the statement that the content of a conjunctive proposition is not affected by a change in the order or in the grouping of its component assertions, nor by their repetition.

6. Hypothetical Inference

Another basic relation between propositions is implication. Indeed, this relation is the most fundamental of all. It has been described in the chapter on " Judgment and Inference." It is illustrated by the assertion: *If two circles cut each other, they cannot have the same center.* The implicative relation may be symbolized thus: *If p is true, q is true;* or, *p implies q.* The first component proposition is called the antecedent, ground, or hypothesis; the second is named consequent. The whole is called a *hypothetical proposition,* because, having supposed certain objects, we assert, not necessarily their existence, but a necessary connection, or relation of dependence, between them.

Let us now examine the use of hypothetical propositions as premises in inference. The following argument illustrates one type of hypothetical inference:

> If a crop is generally excellent, its selling price will be low;
> The crop of wheat is generally excellent;
> Therefore, the price of wheat will be low.

The first or major premise is entertained hypothetically; in this case, it is an economic law. The minor is a categorical proposition derived directly from experience. From these two premises we infer a categorical conclu-

sion. Thus, the hypothetical major is the rational link between two categoricals: from *p true*, and *p implies q*, we infer *q true*. *The hypothetical syllogism* is another name for hypothetical inference. *Syllogism* is derived from a Greek word which means *to reckon together*, or *to think together*. If the minor premise of a hypothetical syllogism is suppositional, the conclusion can be only formally valid. It may not be true of experience, and cannot be used for purposes of further inference.

The minor premise in a hypothetical syllogism may have any one of four relations to the major: it may affirm or deny (that is, agree or disagree with) the antecedent; it may affirm or deny the consequent. In the above example the antecedent was affirmed. The four forms, with the same major premise, may be represented as follows:

VALID MOODS:

1. *Constructive*: if *p* implies *q* and *p* is true, *q* is true.
2. *Destructive*: if *p* implies *q* and *q* is false, *p* is false.

INVALID MOODS:

1. *Fallacy of Denying the Antecedent*: if *p* implies *q* and *p* is false, *q* is indeterminate.
2. *Fallacy of Affirming the Consequent*: if *p* implies *q* and *q* is true, *p* is indeterminate.

These formulas are fundamental laws of thought. They clearly define the meaning of logical necessity. They may be usefully summarized in *the rule of hypothetical reasoning: to obtain a valid conclusion, the minor premise must either affirm the antecedent or deny the consequent.* When the minor premise does the opposite, the above fallacies result. A subtle form of affirming the consequent consists in inferring that the arguments advanced for a thesis are necessarily sound because the thesis is true.

The reason for the rule of the hypothetical syllogism is that frequently we must leave open the possibility that a consequent may be due to any one of several antecedents. When this is true, the denial of one antecedent would not allow us to deny the consequent, nor could a particular antecedent be certainly inferred from the truth of the consequent. However, as our knowledge of a particular consequent becomes more exact and complete, we may find that it could be produced only by a specific antecedent. Thus, the symptoms of some bodily poisons are so definite that the trained medical practitioner may readily deduce the precise chemical cause. When antecedents are thus fully defined, the relation between antecedent and consequent becomes logically reciprocal; we can infer either from the

other. Our knowledge has attained systematic form. When we draw a conclusion by eliminating possibilities that are exhaustively enumerated, our reasoning usually takes the disjunctive form, which will be described below.

7. Subsumptive Inference

Subsumptive inference, or *the categorical syllogism,* is another common kind of deduction. It is often called simply " the syllogism." It is useful in applying any general formula to a particular situation, as in engineering or applied mathematics. It is also valuable in problems of classification. Imagine, for example, a botanist discovering the ginkgo tree. In the process of examining it he finds that, while it possesses peculiar characteristics, it also shares some of the salient properties (*e.g.* naked seeds) of a large class of well known plants (gymnosperms). Because of the latter *common* characteristics, the plant is *subsumed* under the large class, which is known as its *genus*. Because of its *peculiar* characteristics, it forms a subdivision or *species* of the genus, perhaps a new species. The thought of the botanist may be formulated thus:

If anything is M it is P.
Since this S is M, it is P.

The mark M (naked seeds) is the common element by which S and P (ginkgo and gymnosperms) are brought into a necessary relation.

The preceding inference is an excellent implicative syllogism. Subsumption is also present in that S as an instance is subordinated to M as a class; in other words, the familiar M is applied to explain the unfamiliar S. *The principle of subsumption* (also called *dictum de omni et nullo*) declares that " what can be predicated of every member of a class, to which a given object is known to belong, can be predicated of that object." [3] Negatively, we infer that if a certain class-mark is not true of a particular individual, the latter is not a member of that class. Thus, we infer that mosses and liverworts are not ferns because they do not possess the set of characteristics that distinguish ferns.

The syllogism is a sequence of subsumptions. A relation between S and P is inferred from their given relation to M. If in the above argument we complete the induction from *This S is M* to *Every* (*or all*) *S is M,* it may be restated in the following typical subsumptive form; we shall add another typical argument with a negative conclusion:

$$\text{A}\begin{cases}1.\ \textit{All } M \textit{ is } P\\ 2.\ \textit{All } S \textit{ is } M\\ \hline 3.\ \therefore \textit{All } S \textit{ is } P\end{cases}\qquad\qquad \text{B}\begin{cases}1.\ \textit{No } P \textit{ is } M\\ 2.\ \textit{All } S \textit{ is } M\\ \hline 3.\ \therefore \textit{No } S \textit{ is } P\end{cases}$$

[3] *Op. cit.*, Vol. II, p. 22.

What we do, then, in subsumptive inference is (*a*) to state the law or mark of a class; (*b*) to range some individual or group under that class (or exclude it), and (*c*) to affirm (or deny) the class characteristics or universal of the subsumed individuals. The relations of subordination will be evident if we arrange brackets (representing classes) according to the arguments thus:

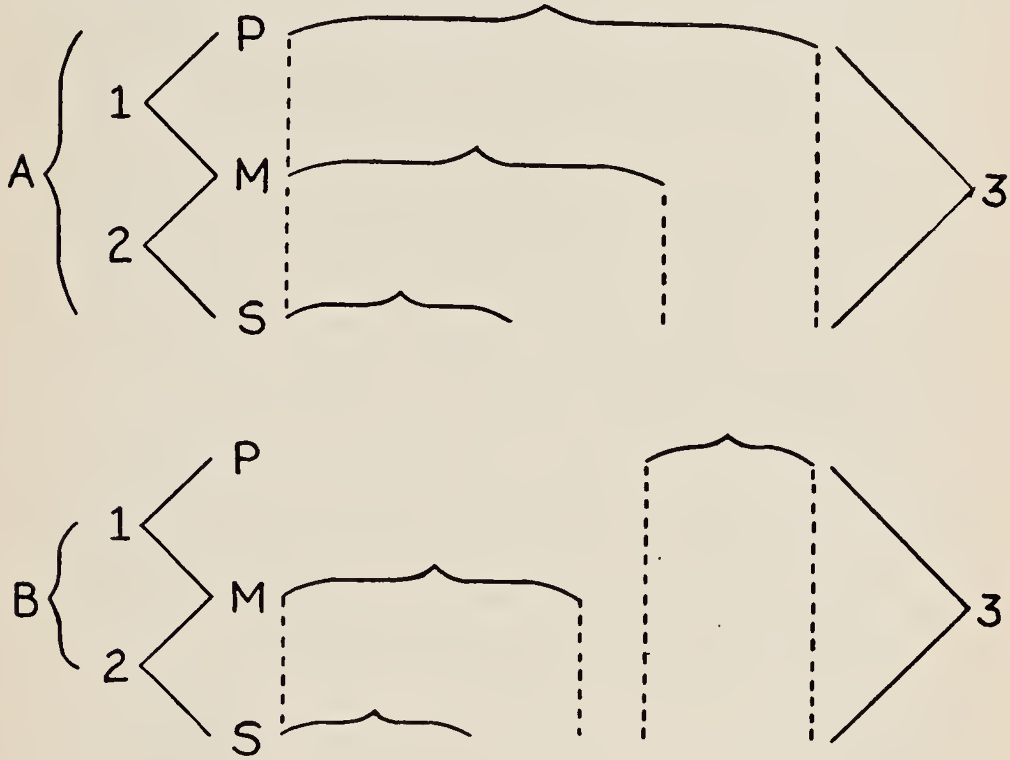

FIG. 19. THE SUBORDINATION OF PROPOSITIONS
Numbers 1 and 2 are premises; 3, conclusions.

Subsumptive inference rests upon the subordination of class terms, as hypothetical reasoning is based upon the implication of propositions. Any implicative or hypothetical argument may be forced, often awkwardly, into the categorical mould. Such a formulation is, however, frequently artificial and misleading, because it emphasizes the quantitative or class-relations of phenomena, whereas our scientific interest centers in their intrinsic attributes or governing laws. Thus, when we assert that *All iron is malleable,* we do not mean that we have examined all instances of iron. We mean rather that malleability is an inseparable property of iron *if* certain conditions of pressure are operative.

(*a*) THE STRUCTURE OF SUBSUMPTIVE INFERENCE. — The structure of the categorical syllogism is evident. It consists of three and only three terms. Since each term occurs twice, the syllogism contains three and only three propositions. These two facts are often comprised among the rules

of the syllogism. Each proposition has one term in common with every other. The conclusion contains two terms in *fixed* order: the subject S is called the minor term, and the predicate P is called the major term. The premises in which P and S occur are called respectively the major premise and the minor premise. The third term which does not appear in the conclusion is called the middle term (M).

If any term is ambiguous, or used in two senses, no valid conclusion can be drawn. The law of identity has been violated, and a *fallacy of four terms* results. *A syllogism, then, is a combination of three propositions whose terms are so interrelated that from two of the propositions alone, called premises, the third proposition, or conclusion, can be inferred.*

One of the three propositions of the syllogism often is not overtly expressed. Such an abbreviated syllogism is called an *enthymeme.* For example, we infer that this patient can have no fever because he is not thirsty. Since all three terms are present in an enthymeme, the omitted proposition is readily constructed. In the example just cited the major premise is suppressed; namely, *All feverish persons are thirsty.*

(*b*) Types of Class Relation. — We have seen how subsumptive reasoning is an elaboration of class relations. There are four possible relations between classes: identity, inclusion, overlapping, and exclusion. Overlapping may exist either in the form of proposition I or of proposition O. The four class relations other than identity are included in the diagram of Figure 20. Circles representing classes are graphic aids in grasping the relations involved.

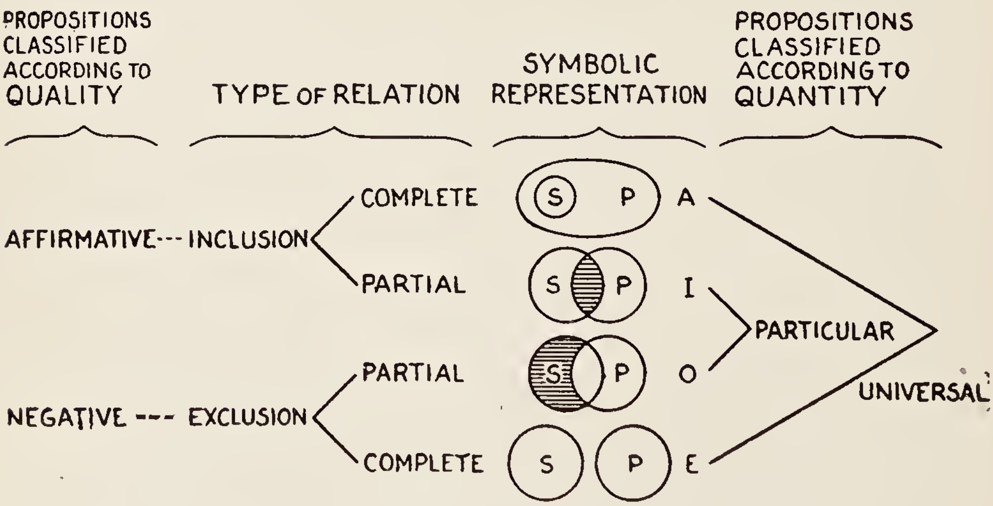

Fig. 20. Types of Class Relation

(*c*) Rules and Fallacies of Subsumptive Inference. — The terms in the premises of a syllogism may stand in four different orders according to the positions of the middle term. These arrangements are called *figures.* The figures are:

First	Second	Third	Fourth
M — P	P — M	M — P	P — M
S — M	S — M	M — S	M — S
∴ S — P	∴ S — P	∴ S — P	∴ S — P

The premises of any figure may be composed of any pair of the four typical propositions, *A, E, I,* and *O.* In all sixty-four such combinations, called moods, are possible, of which nineteen, or thirty per cent, are valid. The validity of any syllogism is tested by applying the following rules.

A. *Rules of Distribution:*

1. The middle term must be distributed at least once.
2. If a term is distributed in the conclusion, it must be distributed in its premise.

B. *Rules of Quality:*

3. No valid conclusion can be drawn from two negative premises.
4. If one premise is negative, the conclusion must be negative; and vice versa.

The violation of the first rule is a very common fallacy, especially in the second figure. Let us analyze the argument that these men must be fundamentalists since they are opponents of evolution. The first step is to state the inference in good logical form:

> All fundamentalists (*F*) are opponents (*O*) of evolution;
> These men (*M*) are opponents of evolution;
> Therefore, these men are fundamentalists.

The major premise does not assert that *F* and *O* are coextensive; so far as it goes, *O* may be larger than *F*. The uncertainty of the conclusion is clearly exposed if we attempt to represent the argument in circles (Figure 21). The dotted circles indicate the possible positions of *M*. The premises permit any one of the five following relations between *M* and *F*: *A, I, O,* both *I* and *O,* and *E*. Where everything is possible, including contradictories, nothing is proved. The error is obvious in the following argument of the same form:

> All freshmen are college students;
> Mr. A is a college student;
> Therefore, Mr. A is a freshman.

The inconclusiveness of the preceding arguments is due to the fact that the middle term is undistributed in both premises. As a result we have no way of determining whether we are comparing the major and minor terms with the same part of the middle term. A sure connection between *S* and *P* by way of *M* is possible only if *M* is distributed at least once.

The second rule formulates the important principle that in deductive inference we are not permitted to pass from *some* to *all.* Consider the argument that this property is not exempt from taxation because it is not

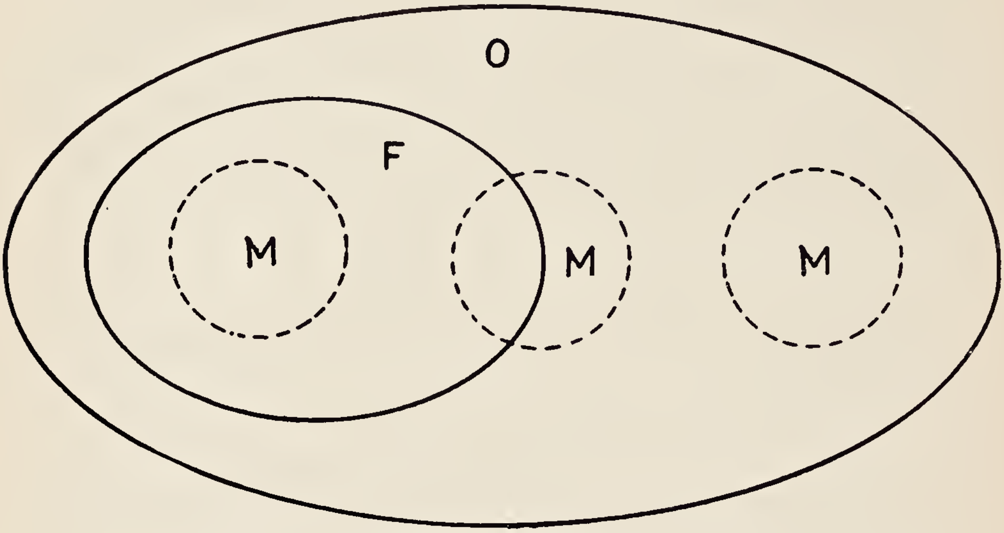

FIG. 21. FALLACY OF UNDISTRIBUTED MIDDLE

church property. This is an enthymeme which may be formally expanded as follows:

All ecclesiastical property (*E*) is property that is exempt from taxation (*T*);
This property (*P*) is not ecclesiastical property;
Therefore, this property is not property that is exempt from taxation.

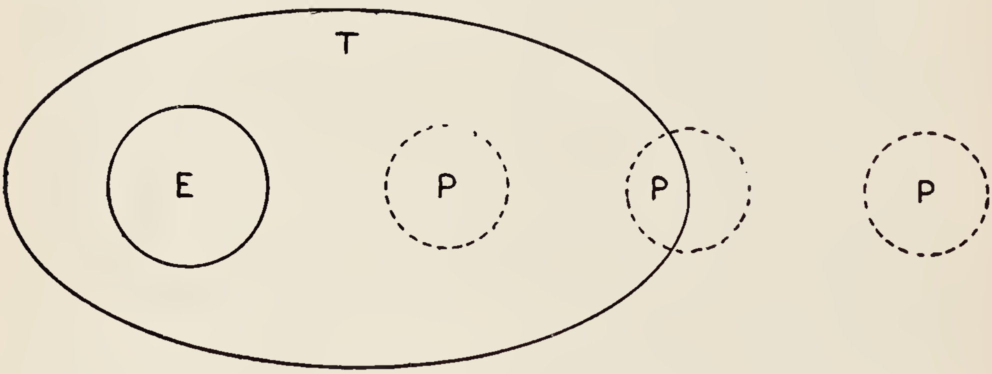

FIG. 22. FALLACY OF ILLICIT MAJOR

It will be noticed that the major term, *T,* is distributed in the conclusion (negative predicate) and undistributed in the major premise; in other words, the argument jumps from a partial to a complete reference to *T*. When the inference is symbolized in circles (Figure 22), the position of *P* is indeterminate. This fallacy is called the fallacy of illicit

major. Any syllogistic argument may be quickly tested by representing it in circles. When the position of one circle is uncertain, no conclusion has been demonstrated. Demonstration is another name for valid deduction.

If the preceding syllogism is translated into implicative form, the result is a fallacy of denying the antecedent:

> If any property is ecclesiastical, it is exempt from taxation;
> But this property is not ecclesiastical;
> Therefore, it is not exempt from taxation.

One method of proving the rules of the syllogism consists in showing that any violation of them, when expressed in hypothetical form, produces a fallacy. If an argument is valid or invalid in either form, it will be the same in the other.

Similarly, in the fallacy of illicit minor, the minor term is distributed in the conclusion when it is undistributed in the minor premise. It is an uncommon mistake. It is illustrated by the following argument:

> All lions are carnivorous;
> All lions are quadrupeds;
> Therefore, all quadrupeds are carnivorous.

The inconclusiveness of this inference readily appears when it is represented by circles.

The third rule expresses the fact that the exclusion of two classes from a third demonstrates no relation between the two. This is evident when circles are drawn. The following argument is an example of the fallacy of negative premises:

> No person who breaks the law is a good citizen;
> This person is not a law-breaker;
> Therefore, this person is a good citizen.

The reason for the fourth rule is that if, in case of terms *S* and *P*, one is excluded from *M* and one included in it, it is evident that they must be mutually exclusive; that is, we can infer only a negative conclusion. On the other hand, an exclusive or negative conclusion cannot be derived from two affirmative or inclusive premises.

Syllogistic fallacies may be grouped according to the rules violated as follows; this arrangement is probably the order of their decreasing frequency:

1. Fallacy of undistributed middle.
2. Illicit major; illicit minor.

3 and 4. Fallacy of negative premises.

The *converse fallacy of accident* is essentially an error in subsumption. It consists in applying a general rule to a particular case that is unusual or peculiar. Thus we might argue that the compulsory sale of land for public use is unjust because it interferes with the individual's right of private property. It is important to remember that special circumstances may make a general rule inapplicable.

8. Disjunctive Reasoning

A disjunctive proposition asserts two or more incompatible predicates of the same subject and raises the question as to which predicate or predicates are true. It is marked by the presence of *either-or* in words or thought; for example: *He is either guilty or not guilty.* This simple form is a particular case of the law of excluded middle. It is the most appropriate way of bringing together the several possible solutions of a problem which a thinker has discovered.

A disjunctive proposition declares: *Either p is true or q or r . . . is true.* Thus, we might say: *Water is either fluid, vaporous, or solid;* or, *Student A is either very clever or very industrious.* The latter example, however, is not a strict disjunction, since *A* may have both qualities. The word *or* is often ambiguous; namely, when it fails to indicate whether the propositions related are mutually exclusive. A proposition in which the alternatives may not be incompatible is called an *alternative proposition;* as, *The plants in this catalog are either new or noteworthy.* It is clearly stated in the form: "*At least one of the propositions p and q is true.*"[4]. If one of the alternatives in such a major premise is denied in a minor premise, we may validly conclude that the remaining alternative (or alternatives) is true. This is a formal statement of the process by which one hypothesis at a time is eliminated from a multiple set.

In a genuinely disjunctive proposition the alternatives are mutually exclusive and collectively exhaustive. It is unambiguously stated thus: *Not both p and q are true.* With this proposition as a major premise, four possible conclusions may be validly drawn according to the nature of the minor premise which is introduced from experience:

Affirmative conclusions: $\bar{q}, \therefore p; \quad \bar{p}, \therefore q;$

Negative conclusions: $q, \therefore \bar{p}; \quad p, \therefore \bar{q}.$

The quality of the conclusion in each case is opposite to that of the minor premise. In implicative reasoning the minor and the conclusion are of the same quality. *The basic rule for obtaining a valid conclusion in disjunctive*

[4] Lewis, C. I., "Implication and the Algebra of Logic," *Mind*, 1912, p. 523.

reasoning is that the alternatives should be definite, incompatible, and exhaustive. Arguments with more than two alternatives may be developed.

The disjunctive syllogism provides the intellectual machinery for dealing with multiple hypotheses. How explain, for example, the actions of the chimpanzees studied by Köhler? One of their achievements consisted in piling up boxes so as to get bananas placed above their reach. This conduct must be due to either instinct, imitation, chance, thought, or some combination of these. Instinct must be ruled out because boxes played absolutely no part in the evolution of the animals. The truth must be found among the remaining alternatives. Since the experimenter had carefully kept from the ape every opportunity of seeing boxes manipulated, imitation also is impossible. Neither were their actions the result of chance, for the solution was not slowly and painfully selected out of many inexpedient movements. Rather, the activities began from a stage of deliberation and continued in an unbroken curve. They always took place with regard to the relevant situation. Their actions, then, must be explained in terms of a perception of the stimulus and a grasping or understanding of the changing meanings of the situation.

Disjunctive reasoning is chiefly valuable in the advanced stages of a science, where systematic knowledge of a given field of phenomena has been obtained. The investigation of apes just mentioned really took place against a background of extensive and precise knowledge of human behavior. Because of that knowledge, the alternatives were readily formulated. Chemical analysis of an unknown substance furnishes a good example of disjunctive procedure. The chemist must first have clearly defined the elements that may possibly be present, and must provide decisive tests for each. He then proceeds in a prescribed order to exclude or to recognize one possibility after another until he finds all of the elements that are actually present. In this case the scientist knows the *class* of phenomena to which the substance belongs, namely, chemical substance, but he does not know its *species*. He knows, however, the species that may be present; namely, the chemical elements. The unknown substance must consist either of silver, lead, mercury, or other elements. Thus, by disjunctive reasoning, we assimilate into a well organized field of knowledge a phenomenon of whose specific nature we are ignorant. This procedure evidently is essentially deductive in nature.

Disjunctive reasoning is of little use outside of organized science because of *the difficulty of obtaining alternatives that are incompatible and exhaustive*. In consequence good disjunctives are rare, and the *fallacy of imperfect disjunction,* or false alternative, is frequent. A common form of this fallacy consists in overlooking as a third possibility the combination of two given alternatives. Such an oversight might be present in the

following assertion: *Mr. A has either inherited much money or has made much money.* Another example of this pernicious and widespread " either-or " type of thinking is found in the not uncommon opinion that a scientist cannot be both a higher critic of the Bible and a devoutly religious person. It is often safest to employ an alternative proposition of the form *Either* p *or* q *or* pq.

The so-called *fallacy of complex question* is a form of imperfect or distorted disjunction. For example, we might ask a man at an art exhibition, " What kind of an artist are you? " This question excludes the alternative of his not being an artist at all. The leading questions of clever lawyers in cross-examinations often so conjoin or disjoin propositions that a true answer to one part of the question may entail a false reply to another part. In this way witnesses are sometimes confused and inveigled into damaging assertions of which they are innocent. One may attack such a complex question either by breaking it up into independent questions and answering them separately, or by restating the alternatives in adequate form.

A combination of hypothetical and disjunctive propositions gives rise to the dilemma. The principle of the dilemma appears when two hypothetical propositions have contradictory antecedents but the same consequent. It may be symbolized thus:

1. If p, then q; and if $\bar{p}$, then q;
2. But either p or $\bar{p}$; 3. Therefore, q.

A proposition must be true if two contradictory propositions both imply it.[5]

To obtain a valid conclusion by means of the dilemma, one must observe the rules of the hypothetical and disjunctive syllogisms. Since most dilemmatic fallacies are due to imperfect disjunctions, one may often " escape between the horns " of a dilemma by proving that one important alternative has been overlooked. One may sometimes " take the dilemma by the horns," that is, disprove the implication asserted in one of the hypothetical propositions.

9. The Functional Syllogism

The subsumptive syllogism gains a far more extended use when a general or functional formula serves as major premise. We shall now describe a kind of deduction which is very widely employed in science, especially in mathematics, physics, chemistry, and technology. *A function or functional formula is essentially an algebraic expression containing one or more terms that are indeterminate or variable.* A variable term is one which has a more

[5] *Cf.* Johnson, *op. cit.*, Vol. I, pp. 37–38.

or less wide range of possible values. For example, the circumference C of a circle is a function of its radius R according to the equation:

$$C = 2\pi R$$

which holds for all values of R. The next step in this kind of reasoning consists in introducing a particular or fixed value for R, say 10. The conclusion C then is calculated by simply multiplying together 2, π, and 10. On the other hand, if we had a definite value for C, we could readily determine R by reference to the same functional equation.

In a similar way, the law of gravitation, Boyle's law, chemical formulas, and a host of other laws, recipes, and rules may be practically employed. *This kind of reasoning consists in substituting either a particular instance or an equivalent value in a given formula.* It may be named the substitutional syllogism, or as Johnson suggests, "the functional syllogism."[6] In essence, it is thinking or doing a particular thing according to a given pattern.

The functional syllogism may be briefly described in general form. *Function* is a mathematical name for a quantity whose value depends upon some other quantity or quantities. That Y is a function of X is commonly written

$$Y = f(X).$$

Y has no determinate value until a specific value, selected from a limited or infinite set of possible values, is assigned to X and the equation solved for that value. The act of substituting a definite value for X is an application of the subsumptive principle already explained. If a capital letter symbolizes a general function and a small letter a specific value, the steps of a functional syllogism may be stated thus:

$Y = f(X)$;
The given instance is x;
Therefore, the given instance is y.

No new rules of thought are needed for this kind of reasoning. The laws of conjunction, identity, and subsumption directly apply. Boyle's law concerning gases is an example of a threefold function; namely, of pressure, volume, and temperature. Unlike the ordinary categorical syllogism, the functional syllogism does not repeat in its conclusion the same major and minor terms as occur in its premises; rather the terms in its conclusion are only particular values out of an indefinite multitude comprehended by the universals of the major premise.

In the functional syllogism the organismic or systematic conception of inference attains clearest expression. The components of such a syllogism

[6] *Cf. idem,* Vol. II, Ch. V and VI.

are so integrally adjusted to one another that any variation in one entails a variation in the rest. The logical unity in a functional system closely resembles the dynamic harmony in a work of art. As soon as an architect who is designing a classical building can decide upon the diameter and the spacing of the columns, the rest of the building follows as a matter of functional reasoning. In functional reasoning disjunctive separation is overcome and we return to conjunction on a higher level; namely, on a level where the systematic framework of inference becomes evident.

(*a*) Reasoning by Substituting Equivalents. — The functional syllogism so far described has concerned the substitution of particular values in a general formula. Another important variety consists in substituting, not instances, but equivalents, in a given case. Equivalence means mutual implication: p implies q and q implies p. A simple form of inference by equivalents is:

$$S = M; \quad M = P; \quad \therefore S = P.$$

The premises contain two judgments of equality containing the common magnitude M. The conclusion is a third judgment of equality containing all but M. Such reasoning obviously may be expanded to any length.

Substitutional reasoning is guided by such evident variations of the law of identity as the following: if each of two things is equal to the same third thing, they are equal to each other; the whole is equal to the sum of its parts.

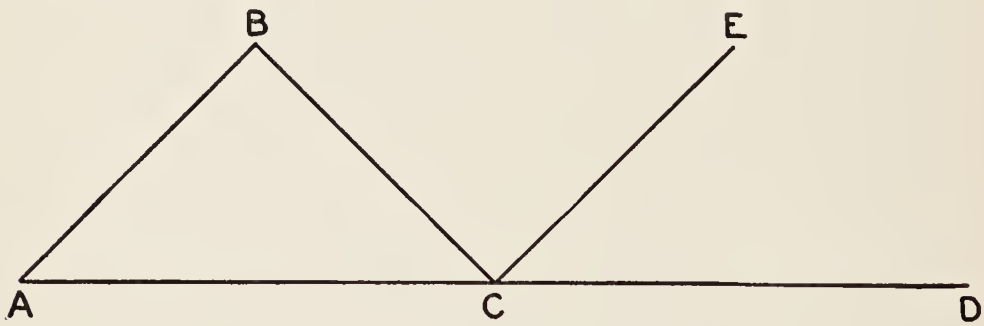

Fig. 23. A Geometrical Proof

As an example of deduction by substituting equivalents we may recall the theorem that the sum of the angles of a triangle is equal to two right angles. The side AC of the triangle ABC is extended to D (Figure 23), and line CE is drawn parallel to AB. By reference to the axiom or previously proved theorem concerning the angles formed by two parallel lines cut by a transversal, we can write the following:

$$S \left\{ \begin{array}{l} BAC = ECD \\ ABC = BCE \\ BCA = BCA \end{array} \right\} M$$

Let us call the sum of the angles of the left column S, and those of the right M. M forms a straight angle, and a straight angle by definition is equal to two right angles (R); hence,

$$M = 2R; \quad S = M; \quad \therefore S = 2R.$$

The assertion that BCA equals BCA is a case in which the law of identity called tautology plays a necessary part in argument. To say that it is an instance or application of that law, however, is to use again the subsumptive principle. In other words, when we give explicit reasons for our substitutions, we appeal to a general principle which covers the instance in question.

The functional and substitutional syllogisms offer an exact and simple way of describing the deductions that are characteristic of mathematics. *Developed mathematical reasoning is a sequence of functional syllogisms.*

(*b*) The Method of Residues. — The so-called method of residues is a case of functional deduction rather than of inductive inference.[7] Suppose, for example, that we know the weight (t) of a loaded vehicle and the weight of the vehicle (v). We wish to ascertain the weight of the commodity (c) on the vehicle. Our problem is quickly solved by substituting definite values in the following equation and solving for c:

$$t = f(c, v), \text{ or } t = c + v.$$

The classical example of the method of residues is the discovery of the planet Neptune by Adams and Leverrier. They noticed certain peculiarities in the movements of the planet Uranus. In order to fit these into a system consistent with the known laws of motion, they had to posit a new planet in a definite location. Later Neptune was observed exactly where they predicted it would be found. Their inferences were functional syllogisms. An understanding of the principles of an organized whole enables us to infer missing parts.

10. Summary of Deduction and of Inference

In all forms of deduction so far considered we have kept in touch with existing things, for every minor premise, and most majors, have been derived from experience. A deductive conclusion is true only when it is validly inferred from well established premises. Validity is judged by relevant rules.

A deductive premise may come from any one of four sources: [8] induction, reflexion, postulation, and other deductions. Reflexion is a process

[7] *Cf. idem.* Vol. II, pp. 117–119.

[8] Avey, A. E., *The Function and Forms of Thought*, New York, Holt, 1927, pp 77–83.

of unearthing presuppositions by a process of philosophical criticism to be discussed in the last chapter of the book. These four sources are illustrated respectively by the laws of physics, the principles of logic, the postulates of mathematics, and the proved theorems of mathematics.

The four kinds of propositions we have studied elaborate " the intelligent use " of the ideas of *and, if, every,* and *or.* A given judgment may be stated in any one of four forms, as follows:

1. Conjunctive: x is a diamond and is a crystalline compound.
2. Hypothetical: If x is a diamond, it is a crystalline compound.
3. Categorical: All x's (diamonds) are crystalline compounds.
4. Disjunctive: x is either not a diamond or it is a crystalline compound.

Each of these relations expresses in a special way the connecting function of judgment.

The principal kinds of inferences which we have studied in this and the preceding chapter may be tabulated in the following table:

Table VII. Types of Inference

- A. Immediate
  - Conversion
  - Obversion
- B. Mediate
  - Inductive
    - Concept-making or primitive
    - Enumerative or summary
    - Law-making
  - Deductive
    - Conjunctive
    - Hypothetical or implicative
    - Subsumptive or categorical
    - Disjunctive
    - Functional

Three important uses of deduction have now appeared, as follows: (1) in *investigation,* or the development and verification of hypotheses; (2) in *exposition,* or the organization of acquired knowledge according to relations of subordination, exclusion, and so forth; and (3) in *application,* the use of definitions or formulas in solving particular problems.

R. F. P.

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CHAPTER XIII

VERIFICATION

The nature of truth has engaged the wits of generations of philosophers. Nor could it be otherwise. If true knowledge be taken as the aim of science, the definition of that sort of knowledge is of prime importance. Verification (from the Latin *verus* = " true ") is the last step in scientific method; it is the testing of supposed knowledge to determine whether it be genuine and worthy of the name " truth." Hypotheses become laws, theories become axioms, as they pass the tests which scientific method imposes. But exactly what is the quality for which the scientist is testing? How can any tests be used until we know what we are seeking?

1. The Definition of Truth

It has been maintained by some philosophers that truth is logically indefinable. To attempt to refer it to its proximate genus and indicate its differentia is futile, they have said, because one assumes the very thing in question. That is, the validity of the defining terms and propositions has been taken for granted, and the supposed definition is, therefore, derivative. How does one know that the differentiae employed are the proper ones? Either one does not know, in which case the definition of truth is spurious; or one does know, in which case it is gratuitous. This argument leads to the assertion that either one has truth to begin with, or one never gets it by any testing process. Since, obviously, there is such a thing as truth, and by that we mean true propositions, this amounts to saying that truth is defined only *denotatively*. One can point it out, and say, " That is truth " ; but any further qualification of it is impossible without tautology. The very thing in question will have been presupposed.

In opposition to this other philosophers have maintained that truth can be defined logically. Truth is like anything else, this argument runs; it exists in a context of other things unlike it in character. To define it logically one indicates the general field in which it is found and then adds its distinguishing characteristics. To say that one has to have it, before one defines it, is like saying one must know what a bicycle is before defining it. Of course one must. Things must be known before they can be qualified, and connotatively defined. But that does not prevent the definition of a

bicycle from being useful in distinguishing it from tricycles and other objects. Certainly it is futile to say that one must know a bicycle before one can define it and, therefore, definition is impossible. Why do we make a definition? We define a bicycle to distinguish it from other things. Given all wheeled objects, how can we know which are bicycles? Likewise, given all propositions, how can we know the true ones from the rest? Without experience one could not even point out bicycles and truths denotatively; and if one has experience enough to point out either, it is by virtue of the characteristics of the objects designated. To explicate those characteristics is to give a connotative definition of the things concerned. This is exactly what we desire with reference to truth.

As a preliminary definition we may say that *truth is a quality which may be possessed by propositions.* In our experience we are familiar with all sorts of propositions. Some we know to be false; others we feel to be dubious. Still others claim our acquiescence at once when we examine them closely. The question is this, *To what kind of propositions do we in fact apply the adjective " true " ?* We shall not expect to find truth, in general, existing apparent to the senses, as we would not expect weight to be separated in time and space from the objects of which it is the weight. But we will attempt to detect the *quality of discourse* which claims the stamp of approval. When put in this way, the question of the nature of truth becomes an intelligible question, and its solution becomes both possible and profitable. For, in defining what we mean by truth, we distinguish the quality, or qualities, which we will seek in future propositions to be similarly designated. In defining truth we are, therefore, classifying propositions.

The question of the nature of truth involves the whole problem of the aim of science. What kind of propositions do we seek with our scientific method? Our scientific method is merely a systematic attempt to conserve and extend one kind of discourse at the expense of other kinds. To define the criteria of truth is to state the goal of scientific method.

2. Truth and Correctness

As we have seen in the discussion of the syllogism, reasoning which may be above reproach, given the premises, may turn out to be untrue because of the falsity of those premises. Take the following reasoning:

All planets are green cheese;
Mars is a planet;
∴ Mars is green cheese.

The thinking is formally correct, but we recognize the conclusion as untrue. One can reason with formal correctness from major premises which

are false, even as an engineer can formally survey a property from wrong starting points. So long as the engineer sticks to the wrong points, the rules of formally correct mathematics will not help him to attain valid conclusions. In like manner, so long as we merely stick to our false, though formally correct, words we cannot detect their falsity by any of the rules of formal reasoning. Truth is a quality which specific discourse has by virtue of its relation to things other than itself; that is, the truth of an argument is as much a matter of extrinsic relations as it is of intrinsic relations.

Let us put the matter differently. The correctness of the conclusion of an argument can be checked in two ways. In the syllogism, —

All men are mortal;
Socrates is a man;
∴ Socrates is mortal —

we may check the conclusion " Socrates is mortal " (1) by referring it, *in discourse,* to the preceding propositions. The argument is *intrinsically* correct; that is, it is not self-contradictory. It is consistent with itself. If truth were merely a matter of the consistency of propositions, we could stop with this intrinsic correctness of discourse. Then any consistent structure of discourse would be true *qua* consistent. But there is another type of correctness. We can test the conclusion also (2) by noting the event to which it points. This extrinsic reference is to the facts in the case: does Socrates die or not? If he dies, the proposition that " Socrates is mortal " is then correct, not, in this sense, because it followed logically, but because it indicated events, *extra-logical* in character in this instance, which proved to be genuine. If Socrates lives forever, then the conclusion " Socrates is mortal " is incorrect, in this sense, although formally it is above reproach; and the fact that the conclusion is *formally* correct, moreover, is part of the ground upon which we would then deny the truth of the major premise or of the minor. If Socrates lives forever, then either " All men are mortal " is false, or " Socrates is a man " is false. Either some men, at least, are immortal, or Socrates is not a man.

Scientific thinking must be correct *in both senses.* We want generalizations (major premises) which by correct, formal deduction yield conclusions which are correctly and specifically indicative of genuine realities. *Where arguments intrinsically correct prove to be extrinsically correct, we have truth.* But what else can we say about the matter?

3. What Are the Criteria?

The test, or standard of judgment, concerning the excellence of anything, whether structure or function, is determined by a study of the natural or normal development of that thing. A criterion is reached by carefully

making explicit the implicit tendencies of any function. What does digestion or respiration naturally aim to do? The answer to such a question is a rough criterion for the testing of specific acts of digestion or respiration. In the same way the question may be asked, What does thought naturally aim at doing? The most notable characteristic of thinking is that something is expected. *Thought is an imaginative anticipation of events.* We respond to stimuli with reference to future stimuli, *i.e.*, in terms of anticipated occurrences. Thought is an activity which has taken upon itself the duty of untangling and avoiding the difficulties occasioned by the conflicts of man's other activities in their environment. It does this by systematically foreseeing consequences. "Forewarned is forearmed," as the old adage goes, and the business of thinking is to forewarn. Discourse which yields accurate anticipations is obviously worth conserving. It affords the opportunity for that preliminary adjustment to the future which it is the primary business of thought to provide. *Predictability,* in other words, is a test for truth. This is the meaning of extrinsic correctness. Those hypotheses which yield, by intrinsically correct reasoning, exact and correct predictions are dignified by the name of *laws,* and form the core materials of every science. The literature of science is filled with examples of the way in which hypotheses are tested in terms of the predictions which they afford.

Lavoisier, in an early bit of work (1770) [1] on the problem of the supposed changing of water into earth, illustrated precisely the use of the criterion of predictability. He found that in distilling rain water from a glass vessel he obtained an earthy residue. He repeated the distillations in hermetically sealed glass vessels; in some cases repeated distillation was carried on for as long as three months. His reasoning, as he gives it in his essay, may be given in tabular form as follows:

Facts which posed the problem:	Earth is formed by the repeated distillation of water in a hermetically sealed glass vessel.	
Alternative *hypotheses:*	(1) the earth has its origin in something external to the vessel and its contents.	(2) the earth has its origin in the vessel and its contents themselves.
Predictions based on alternative hypotheses:	(1′) as the earth forms, the weight of the vessel and its contents will increase.	(2′) as the earth forms, the weight of the vessel and its contents will remain the same.

[1] "On the Nature of Water and on the Experiments adduced in Proof of the Possibility of its Change into Earth." *Oeuvres* II, pp. 1 f. *Cf.* Freund, *The Study of Chemical Composition,* Cambridge University Press, 1904, Introduction, from which the tabulation of Lavoisier's reasoning has been adapted.

The events indicated by prediction (2′) were actually observed. Hypothesis (2) was consequently verified, and the facts observed during the verification were used as a basis for further inquiry.

Second *problem:*	If the weight of the vessel remains constant, what is the source (within the vessel) of the earth which appears?

Here three alternatives, or multiple hypotheses, appeared:

Alternative *hypotheses:*	(1) the earth comes from the vessel.	(2) the earth comes from the water.	(3) the earth comes from the vessel and the water.
Predictions based on these hypotheses:	(1′) the vessel will lose weight, and this loss will be exactly equal to the weight of earth formed.	(2′) the weight of the vessel will remain the same.	(3′) the vessel will lose weight, but not to the extent of the weight of earth formed.

The prediction (1′) proved to be the correct one, thus validating the hypothesis in terms of which it was made. Lavoisier concluded: " Therefore, it was clearly shown that it was the substance of the glass itself which had supplied the earth separated from the water during the digestion, that what had happened was merely a solution of the glass."

Hypotheses which make possible correct predictions are true. To put it differently, *if the predicted results are identical with the observed results, the theory in terms of which the prediction was made has been verified.* If one predicts an eclipse at 9:30 tomorrow morning and the eclipse occurs, the eclipse which occurs is the same as the one predicted. That is, correspondence is not the test. The atomic theory is regarded as verified, though atoms have never been seen; and how could the theory of the fourth dimension be said to " correspond " to anything? Predictions do not correspond with realities. When they are correct, they indicate realities; when they are incorrect, they indicate nothing beyond the falsity of the theories in terms of which they have been made. If an eclipse is predicted and none occurs, the whole set of notions in terms of which the inaccurate anticipation was made stands as discredited as does the theory that fevers are caused by demons. It is a gross blunder; thought has failed to keep in touch with real events. But if the predictions are correct, the hypothesis may be classed as a true one; a greater and greater reliance will be placed on it in the future. In subject-matters which afford opportunities for manipulation,

attempts will be made in terms of it to prevent or facilitate the appearance of anticipated events. This leads us to our next point.

Thought does not predict idly and to no purpose. It predicts in order to modify. It did not originate in astronomical science, but among short-range events. Having so originated, it has done what it could among events beyond manipulation. Its origin is explicable, however, only in terms of occurrences within reach. To anticipate where one can *change* is a real achievement, and natural selection has produced in man an animal who systematically can perform his adjustments in this forehanded manner. Theoretically everything is predictable, but a great many predictable events will not happen. And some of them will fail to happen because their appearance is prevented.

This introduces us to the criterion of *control.* Events may be controlled through accurate prediction. Prediction is attempted, indeed, in the interest of control. A medical science would be ridiculous which said: "The child has diphtheria; it will die at four o'clock tomorrow morning," and then did nothing but await the death as a triumph of scientific accuracy. Instead, medical science says: "The child has diphtheria; it will die *unless something is done*" — and then it goes on to specify what should be done to prevent the occurrence of the undesired event. This we may call *negative control;* an event is anticipated and an effort made to prevent its appearance because of its undesirability. The test of truth in some fields is just this ability to yield systematic predictions in terms of which we can prevent certain types of events. *Positive control* is, as the name indicates, the type of control which facilitates the appearance of an anticipated event rather than operating to prevent it. Where manipulation is possible, in terms of specific predictions, we try to prevent the undesirable and to produce the things we wish.

4. Summary of Scientific Method

A diagram of the processes attending verification may be made as indicated on the following page.[2] (Fig. 24.) In the diagram the letters X and X′ are the data upon which the reasoning rests; X starts the problem and X′, as the *observed results,* concludes it. 1 and 2 are alternative inductive inferences, *e.g.,* those of Lavoisier as given above; these are attempted statements of the R (relation between X and X′), which is assumed to be a *constant* relation (c). 1′ and 2′ are specific predictions of anticipated results (x′ and y). In the diagram hypothesis 2 is validated by virtue of the fact that the results predicted in terms of it are identical

[2] The author wishes to acknowledge his debt in logical theory to Professor John Dewey.

with the observed results (*cf.* Lavoisier). The two symbols X′ and x′ represent, of course, an identical event.

The place occupied by *consistency* in the diagram below is noteworthy. Consistency has been emphasized by various writers as an ultimate test of truth. It is, of course, the absence of contradiction within any given set of symbols. It is intrinsic correctness in reasoning. Any prediction must be consistent with the hypothesis in terms of which it is

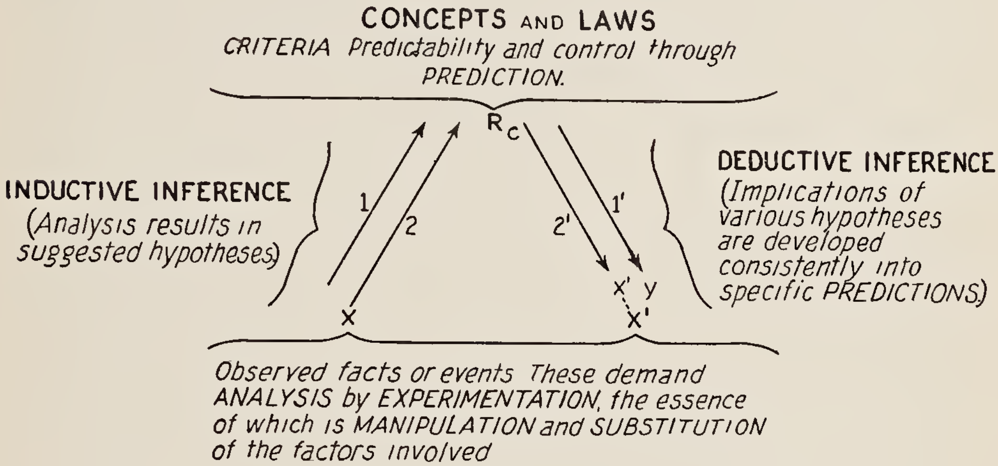

Fig. 24. Summary of Scientific Method

made, else its accuracy or inaccuracy will be no index of the truth or falsity of any hypothesis. But, as a final test of the truth of a theory, consistency is inadequate. It limits the testing of the adequacy of discourse to discourse itself. In methodological disciplines, such as mathematics and logic, the consequences in discourse of the use of an hypothesis are important; but all discourse, including the abstract or methodological disciplines, finds its ultimate verification in the total economy of man's entire experience. In other words, consequences both *in discourse* and *out of it* must be considered; and the test of logical consistency would confine our verification exclusively to the former. Copernicus was inconsistent with previous astronomy; Friedrich Wohler was inconsistent with previous chemistry when he produced the organic product urea in his laboratory. If consistency were a final test, our astronomy would still be geocentric, and there would be no science of organic chemistry. Consistency is, therefore, an evidence of methodological exactness and precision; it is comparable to the nicety of a well-edged tool. But the tool may be utterly useless. So any particular hypothesis and its implications may be worthless.

But the utility of the test of consistency appears when we say that only by testing the implications consistently drawn from a theory can it be

condemned as false or accepted as true. As the illustration taken from Lavoisier indicates, the predictions must be consistent with their respective hypotheses, but the hypotheses are themselves mutually inconsistent. Indeed, the richer the process of multiple hypothesis becomes, the less the consistency apparent among the various sets of symbols used; but the chance of a correct prediction becomes greater by virtue of the increased exhaustiveness of the intellectual work going on. The emphasis upon consistency is, therefore, an insistence upon methodological exactitude *within a given system of symbols.* As such it is commendable. But the scientific test of any set of symbols takes place in terms of the specific predictions and controls which that system makes possible.

5. The Nature of Error

Many logical theories have gone to pieces when faced with the problem of explaining the nature of error. False notions can be held as tenaciously, stated as clearly and distinctly, and taught almost as easily as true ones. In terms of the position here taken, a false notion is simply a *misleading* one, an idea which yields incorrect instead of correct predictions. But how, exactly, does the misleading take place?

One of the stock illustrations of the problem of error is that of the bent stick. The stick is a straight stick, yet it appears as bent when placed in the water. This illustration is sometimes used to prove the illusory character of sense experience. If some of our senses mislead us so badly, perhaps all of them do, the argument may run; and then resort may be had to some rationalistic system of validation for sense experience.

Upon analysis, however, it is apparent that sense experience is not at fault in our judging the stick to be bent. Our eyes give us the broken perspective of the stick resulting from the immersion of part of it in water. If they did not give us this, we should have to revise the laws of optics, and incidentally our eyes would not be as useful as they now are. The error comes in when we *infer* something from the broken perspective. The stick does appear bent to our eyes; we infer that it will feel bent when followed by our hands or used in other motor adjustments of our muscles. Usually a stick so appearing when used in motor adjustments turns out, in use, to be what we call in discourse " bent." So we expect " bentness " to be the quality of this one also. But we have not been reacting previously in two mediums, but only in one (the air). The introduction of the second medium (water) makes it inevitable that we should be misled. Our habits are not adjusted to the demands of this novel situation. We reach into the water, and the stick is not where it should be in terms of our previous habits. We make a *mistake,* literally. The coördination between hand and

eye has been thrown out of adjustment. Because the bulk of our adjustments to the stick are in terms of muscles other than those of the eye we represent them by the term " the stick." " The stick is not *really* bent," we say, " our eyes have tricked us." But if we had been spearing fish for years, and were accustomed to judging from one medium to another, we should not make an error at all. Our eyes have not tricked us; they revealed all there was to see, and further analysis does not change the broken character of the visual perspective, but enables us to form other, more adequate, muscular coördinations.

All error is of this sort. In the realm of sense, as Aristotle said, there is no truth or error, because these distinctions are irrelevant. But when something is predicated, something asserted as expected, then error as well as truth is possible. An erroneous theory is simply a misleading hypothesis, the expression in discourse of an anticipation never to be realized. Whether a natural impulse or a habit, or the lack of proper impulse or habit, misleads us in our anticipation, the result is the same — a mistake in judgment.

6. Truth and the " Will to Believe "

It is readily seen that the *emotional congruity* of a theory has nothing directly to do with its truth. Some Indian may want to believe that he is the richest man in Oklahoma, but his " will to believe," to use the phrase of James,[3] has no bearing upon the truth of the proposition stated. If the man concerned is the richest man in Oklahoma, his stock-and-bond list, bank deposits and real-estate holdings, upon examination and comparison, will be found to be larger than those of any other one person within that state. If these predicted results are identical with the observed results, or subsequently become so, the proposition may be said to be true.

A " will to believe " that has real bearing is a will to test or to verify; it is a will to know or to do. Man's knowledge and his hopes must be kept carefully distinct. It is one thing to hope that a proposition is true; it is another to attempt to verify that proposition. It is yet a third thing to assert the proposition as true. It is perfectly intelligible to hope that there are intelligent living beings on Mars; it may be intelligible to try to verify such a hypothesis. It is certainly foolish to assert dogmatically, as a truth, that there are such beings on our neighboring planet. The furthest we can go scientifically is the assertion that there is seasonal vegetation present. The faith which is necessary to the scientific mind is not a faith which asserts the truth of unproven, or unprovable, propositions. It is a faith in

[3] James, William, *The Will to Believe and Other Essays*, New York, Longmans, 1897.

scientific method which motivates the individual thinker to learn what can be learned and to admit his ignorance when it cannot be helped. The assumption that one must believe a hypothesis in order to test it is only a confusion in scientific method. The whole notion that one has a right to believe things which one does not know rests upon a misunderstanding of the nature of the *positive control* which we have already mentioned. Believing that there are intelligent beings on Mars cannot, by any possible stretch of the imagination, have any bearing on the truth of the proposition that such beings exist. Belief in such a proposition must follow after adequate verification.

The fallacy in the position of James with reference to those situations, to use his words, " where faith in a fact can help create the fact " lies in his failure to distinguish the *possible* truth from the *actual* truth. The young girl whose lover is trying to win her, to use an illustration from James, may actually love her suitor now, or she may come to love him later. It is true that he must believe in the *possibility* of success in his affection in order to carry on. But the belief that she now loves him *actually,* instead of heightening his wooing, could tend only to make him overconfident. The belief that the child sick with diphtheria is *actually* not in danger might enable its parents to get a good night's sleep, whereas the belief that it might possibly, and *possibly not,* be saved from the ravages of the disease would cause them to work all night to secure that end. The child, of course, may be safe already; but so long as there is lacking a complete verification of that proposition there is a moral obligation upon those responsible in such a case, to act as though it were not true. Nor does this involve belief that the child is certain to die. It simply involves the recognition that, when we are in contingent situations, which may eventuate in either direction, it is folly for us to believe that we are not in such situations. The young man may think of himself as possibly successful in his suit, and finally win his heart's desire. The father and mother may believe that their child has a chance against diphtheria, and the child may live. Even our poor Indian may believe that he can make himself the richest man in Oklahoma, and by proper purchase of oil wells he might do so. But premature belief in success can do nothing else so well as cut the nerve of effort.

He who believes what he does not know is as stupid as the man who refuses to admit what is obviously true. Neither can possess a high order of intellectual integrity. *There is a profound obligation, recognized by every scientific mind, to believe upon sufficient evidence and upon that alone.* But there is every justification for *working* for the things we anticipate. We realize our hopes by predicting events which appear as good, and which

we may realize subsequently in action. To attempt such realizations is the ordinary business of intelligent living.[4]

P. W. W.

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[4] It is evident that verification is a matter of testing hypotheses in terms of their consequences in use. In argumentation resort is frequently made to other and inadequate bases of proof. These lead to fallacious conclusions. A bare indication of certain types of these is sufficient to indicate their character. The *argumentum ad hominem* is an appeal to the character, profession, or principles of an opponent instead of to the facts that bear upon the point at issue. The *argumentum ad populum* is an appeal to the passions and prejudices of people rather than to relevant evidence. This may take the form of an appeal to sympathy or pity (*argumentum ad misericordiam*), of an appeal to fear or distrust, or of an attempt to prove a proposition by demonstrating that one cannot demonstrate its opposite (*argumentum ad ignorantiam*). Other fallacies may occur in argumentation as follows:

a. *Shifting the ground* or confusing the issue by appeal to vague generalities, "constitutionally," "law and order," etc.
b. *The appeal for delay:* the effort to postpone decision or discussion in the hope of eluding it, by suggesting such things as: "no need for change"; "let us be moderate and careful"; "a more favorable day will come"; offering of substitute measures; etc.
c. *The fallacy of the neglected whole* consists in piecemeal or one-sided thinking with reference to the whole setting of a problem.
d. *The fallacy of objections* consists in wrongly assuming that a proposition is mistaken because there are certain objections to it.
e. *Non-sequitur* consists in asserting a conclusion which has no rational connection with the premises.
f. *Argumentum ad baculum:* an appeal to physical force to settle an argument: *e.g.,* the duel.

CHAPTER XIV

DISCOVERY

1. The Nature and Fields of Discovery

The most distinctive and stirring phase of human thinking is the moment of *discovery, the act of obtaining the first clear knowledge of something previously unperceived or unknown.* This act is always creative in two respects: for the discoverer, in being a novel combination of ideas; and for society, in being unprecedented in the life of the community.

The need and opportunities for discovery today are multitudinous and alluring. Fundamental inventions such as the wheel, electricity, wireless telegraphy, or representative government, beget in alert minds a host of others. A good theory usually brings with it more problems than it removes. The wide fields of exploration may be roughly divided into four overlapping areas: mechanical invention; social, moral, and religious innovations; artistic creations; and the attainment of new truths, or scientific discovery.

In these fields various psychological, logical, and social factors which facilitate discovery may be defined and deliberately employed. An urgent need exists at present for a comprehensive study of the controllable conditions which promote invention.[1] The logic of discovery is commonly neglected in scientific methodology. The following outline of general conditions favorable to discovery may suggest some directions in which this deficiency might be remedied.

2. The Natural Spontaneity of Man

The strenuous activity of great discoverers first strikes our attention. They seem driven by an almost ungovernable desire to find an outlet for their energies which shall have definite and satisfying form. This creative activity is an intense expression of that original spontaneity and of those endless wants which make every man an explorer by nature. In man's adaptation to his changing and perilous environment he frequently devises novel forms of conduct. When need does not dominate his behavior, he often exhibits a natural overflow of restless and playful self-activities; he

[1] *Cf.* Carmichael R. D., "The Logic of Discovery," *Monist*, 1922, pp. 569–608.

tries to do things which just now need not be done.[2] Even his imitative actions often go beyond their models and are completed with individual variations.

The demands of personal and social expansion, the allurements of fame and fortune, concrete failures and successes, and the pure love of truth, may provoke and direct research. Distinguished discoverers realize more perfectly the inventive powers which all possess in some measure and which may be trained and improved. In short, *an ardent and enduring desire to produce something new, harnessed to a steady and instructed intellect, is favorable to discovery.*

3. The Contribution of Tradition and Technique

Most discoveries, whether of a child or of a mature genius, are outgrowths of whatever thought-organization has already been achieved. Philologists, therefore, do not invent electrical appliances, and violinists do not produce geometrical theorems. *Another basic condition for obtaining new truths is a free and masterful knowledge of those already known.* The great English philosopher, F. H. Bradley, said, near the end of an unusually productive life, "If I had succeeded in owing more to the great thinkers of the past, I might then perhaps have more of a claim to be original." [3]

The explorer should have worked so thoroughly and long in his chosen field that he is both familiar with its achievements and skilled in its technique. In many arts and sciences hypotheses are suggested only to those who have an expert knowledge of their peculiar methods. Harvey could not have discovered the circulation of the blood had he not been taught all that had been previously learned of anatomy. Before Edison begins experimenting on his own account, he ransacks all available knowledge that bears upon his particular problem, and then, he says, "I start where the others left off."

In the following paragraph Emerson shows the debt of genius to tradition:

> Great men are more distinguished by range and extent than by originality. . . . The greatest genius is the most indebted man. . . . In point of fact it appears that Shakespeare did owe debts in all directions, and was able to use whatever he found; and the amount of indebtedness may be inferred from Malone's laborious computation in regard to the First, Second, and Third Parts of Henry VI, in which, "out of 6043 lines, 1771

[2] *Cf.* Royce, Josiah, *Outlines of Psychology,* New York, Macmillan, 1903, Ch. XIII, "The Conditions of Mental Initiative."

[3] *Principles of Logic* (ed. 2), Oxford University Press, 1922, p. viii.

were written by some author preceding Shakespeare, 2373 by him, on the foundation laid by his predecessors, and 1899 were entirely his own." And the preceding investigation hardly leaves a single drama of his absolute invention. . . . It is easy to see that what is best written or done by genius in the world, was no man's work, but came by wide social labor, when a thousand wrought like one, sharing the same impulse.[4]

4. Observation and Analysis as Conditions of Discovery

Keen and extensive observation and analysis are indispensable in exploration. There is no substitute for the venturesome and persistent search for unprecedented data. The man who first saw a piece of native gold, ate roast pig, or felt an electric shock made a discovery. The amazed Galileo with his new telescope was the first human being to see the mountains of the moon, the satellites of Jupiter, and the marvelous glowing rings of Saturn. His discovery illustrates how new knowledge often is gained by devising new or improved apparatus or methods of procedure. After making an extraordinary number of notable discoveries, Helmholtz declared that in his experience the gift of observation contributed most.

Important discoveries sometimes result from an analysis of simple or of exceptional phenomena. The Danish scientist, Finsen, got the suggestion for his famous light cure from watching a cat stretch himself out in the sun. In the history of chemistry, slags, soots, tar, cotton seed, and other waste products have been rich mines for new knowledge. Of Charles Darwin his son said that " the power of never letting exceptions pass unnoticed seemed to be of special and extreme advantage in leading him to make discoveries." [5] Thorough analysis prepares the exact elements of a problem so that the mind may be more likely, at some moment, to hit upon a solving idea.

5. Reasoning by Analogy

An explorer needs an " electric aptitude for seizing analogies." He must be sagacious in discerning the similarities which may lie beneath superficial differences. Darwin's inference from artificial to natural selection and Franklin's assimilation of lightning to electricity are memorable instances of reasoning by analogy. Alexander Graham Bell expressed his basic steps in the discovery of the telephone thus: " If I could make a current of electricity vary in intensity, precisely as the air varies in density, during the production of a sound, I should be able to transmit speech telegraphically." [6]

[4] *Representative Men*, Vol. IV of *The Complete Works of R. W. Emerson*, Boston, Houghton, Mifflin, 1903; p. 195; quoted with permission of publishers.

[5] Quoted by Spiller, G., *A New System of Scientific Procedure*, London, Watts, 1921, pp. 309–310.

[6] *Bostonia*, Boston University, June, 1922, pp. 187–194.

Analogical inference may be formally represented as follows:

> A well-known object O has property P;
> An unfamiliar object X resembles O in some important respects;
> Perhaps, therefore, X also has property P.

That mind is best prepared for discoveries by analogy which is most richly furnished with basic ideas and points of view through which to look at strange phenomena.

Analogy often suggests hypotheses but never proves them. It must, therefore, be used with great circumspection. A good analogy requires a fair degree of similarity in essential characteristics, and must not be based upon accidental or fanciful resemblances. Crucial differences that outweigh points of similarity are easily overlooked, as when Wilhelm II compared American ships on the high seas to peasants' carts in no-man's land; neither, he said, could claim compensation for their losses. The method of dealing with mind as with a chemical compound, or with society as a living organism, has produced a cloud of misunderstandings and errors. Mistakes in this kind of reasoning are called *false analogies* or superficial resemblances.

6. The Comparative Method

Whenever we can compare a phenomenon in some new relation we are likely to obtain new knowledge. All inductive methods are essentially forms of analytic comparison. " By deliberate comparison," declares G. F. Stout, " I mean a mental confronting of two objects, and a transition of attention from the one to the other, so as to discover some respects in which similar things differ in spite of their similarity, or in which different things agree in spite of their diversity, and also a fixing of the precise nature of this agreement or difference." [7]

The so-called comparative method adds to inductive procedure the idea of *widespread and systematic search* for significant analogies. It is the process, says Wundt,

> *of observing many different but related objects and of arranging them according to their types and kinships.* Its purpose is to gain thus a complete picture of the manifold forms in which a phenomenon may appear and to take account of the circumstances of its variation. In comparative anatomy, for example, the inquirer pursues the study of one and the same group of organs, wherever possible, through the whole animal kingdom, or at least through a large number of related species, in order to establish in this way the different forms of their development.[8]

[7] Stout, G. F., *Manual of Psychology* (ed. 2), New York, Noble and Noble, 1901, p. 452. Used by special permission of the publishers.

[8] *Logik* (ed. 4), Stuttgart, Enke, 1920, Vol. II, pp. 368–373.

The same method of discovery is employed in comparative philology, religion, psychology, and other sciences called comparative. It is always instructive, for instance, to trace such an institution as marriage, animal worship, or human sacrifice through its variant forms in different tribes and epochs of the world. As a result of painstaking analysis and comparison, Biblical scholars have succeeded in isolating and describing the principal documents (designated J, E, D, and P) which compose the Pentateuch.

7. Logical Synthesis

Since discovery is essentially a novel combination of ideas, everything that aids original inductive or deductive synthesis favors discovery. Sometimes discoveries may be achieved by combining or extending known devices, concepts, or laws. Sewing, knitting, and adding machines, the clock and the automobile, are a few of the many mechanisms which are novel combinations of elementary notions which were well known at the time to the educated public. Successful discoverers have a way of generalizing upon previous observations and solutions, and of consciously carrying over to later problems the principles and techniques already validated.

Deductive reasoning in various forms may also yield discoveries. History furnishes a multitude of examples of how minor inventions may be inferred from major ones. Thus, if one knows that heat expands liquids in proportion to their temperatures, he may deduce the thermometer; from similar knowledge concerning metals he might infer the thermostat.

A knowledge of the general structure of a system often enables us to fill in certain details which we had not known before. Mendeléeff, for example, from his understanding of the periodic table of chemical elements, predicted and described three unknown elements which others soon discovered. The models of molecular structure which the organic chemist builds furnish the ground from which he may deduce numerous new compounds.

8. The Use of Hypotheses and Postulates

A supposed discovery of a truth is called an hypothesis. It is a provisional explanation of observed facts, a tentative guess as to the solution of a problem. It corresponds in knowing to the working themes, plans, or models in art and practice. Its important function is to furnish the inquirer with a directing idea by which to carry forward his investigation and criticism.

A good hypothesis fulfils certain requirements. It should be as definite and clear in conception as possible, and also appropriate and adequate to account for all relevant facts. It should be as simple as the data warrant, and in harmony with the body of established knowledge, except where it

claims to correct or modify that knowledge. It must by all means be susceptible of proof or disproof. Finally, a good hypothesis enables the explorer to anticipate experience, to make significant deductions which may guide him in further study.

An explorer may deliberately set up postulates in order to see what significant conclusions he can deduce from them. This kind of rigorous deduction from acknowledged suppositions has been called postulational thinking.[9] While its procedure was briefly outlined in the chapter on mathematics, it is a general method which is applicable in physics, economics, politics, or any other field, the subject-matter of which is amenable to exact definition. Postulational thinking has been used with conspicuous fruitfulness in the study of mechanics, electricity, and atoms.

The Italian philosopher, B. Croce, in his *Autobiography,* writes as follows concerning his excursions into socialism and economics:

> The astonishment, nay even the stupor, of certain of my friends who were economists by profession was equally great when in our conversation they perceived that I indeed was embarrassing them. For I had become complete master of the fundamental concepts of their science, and I was deducing the consequences of these concepts with inflexible and logical intransigience in a field where undoubtedly they had more extended information than I, but where their knowledge was not carried, as was mine, into a solid system.[10]

The postulational thinker explores, on the wings of pure thought, vast realms of uncharted possibilities, contemplating, supposing, deducing. He does not fear or shun radical speculation, but openly adopts it as a self-conscious tool for gaining new knowledge. He enters the free realm where creative artists and thinkers manipulate carefully selected materials according to self-imposed rules. As he builds one deductive system after another, novel and significant relations may appear among his assumed terms. Then when he returns to the real world with the eyepieces of creative thought, he may sometimes see there striking new relations or concrete applications which the fact-bound empiricist and utilitarian had never suspected. Postulational thinking thus turns guesswork and the disciplined imagination into the methodical service of science.

Fertility and boldness in making conjectures, and freedom and versatility in playing ideas upon one's problems, are important qualities of the explorer. Darwin once said, " I cannot resist forming hypotheses on every

[9] *Cf.* Keyser, C. J., *Thinking about Thinking,* New York, Dutton, 1926; and Carmichael, R. D., *Monist,* 1923, Vol. 33, p. 513–555; 1924, Vol. 34, pp. 563–595.

[10] " Critique de moi-même," *Revue de Métaphysique et de Morale,* 1919, Vol. 26, p. 16.

subject"; and John Dewey declares, "Generally scientific power is in direct ratio to ability to imagine possibilities."[11] William James asserts:

> In the highest order of minds we have the most abrupt cross-cuts and transitions from one idea to another, the most rarefied abstractions and discriminations, the most unheard-of combinations of elements, the subtlest associations of analogy; in a word, we seem suddenly introduced into a seething caldron of ideas, where everything is fizzling and bobbing about in a state of bewildering activity, where partnerships can be joined or loosened in an instant, treadmill routine is unknown, and the unexpected seems the only law.[12]

9. Accident and Inspiration in Discovery

Few important discoveries are due to accident. Charles J. Kintner, formerly of the Patent Office, once truly declared, "The aspiring inventor should learn once for all that there is no royal road to success in invention, and that the *accidentally* successful inventor is *not one among ten thousand.*"[13] Some discoveries have been unexpected by-products of methodical experimentation on allied problems. In this way Pasteur hit upon immunization by inoculation, and Röntgen was the first to see the bones of his hand by means of X-rays. Fortunate "accidents" happen only to those observers whose minds are prepared to recognize the significance of an event. As Bulwer-Lytton said, "Chance happens to all, but to turn chance to account is the gift of few."

It sometimes happens that a well-fitted mind suddenly becomes conscious, during periods of comparative repose, of creative ideas which the most strenuous thinking had failed to bring forth. They break into consciousness at unforeseen moments with power to illuminate and unify the baffling and scattered elements of a problem just as a crystal particle dropped into a saturated chemical solution may precipitate the crystallization of the whole. Such sudden and significant insights, the sources of which are unperceived at the moment, are conveniently called discoveries by inspiration.

While we are largely ignorant of the precise causes of these creative irruptions, we do know that they tend to occur when vigorous intellectual activity is punctuated with liberal periods of change, relaxation, and quiet contemplation. *One of the most important rules, therefore, for promoting*

[11] "Some Stages in Logical Thought," *Philosophical Review*, 1900, p. 484.

[12] James, William, *The Will to Believe and Other Essays in Popular Philosophy*, New York, Longmans, Green, 1903, Essay No. 7, "Great Men and Their Environment," p. 248; quoted with permission of publishers.

[13] Quoted by Thompson, E. P., *How to Make Inventions* (ed. 2), New York, Van Nostrand, 1893, p. 156.

discovery is to provide these generative periods of repose. Graham Wallas distinguishes three steps in the formation of a new idea: preparation, incubation, and illumination.[14]

Eminent discoverers provide occasions for imaginative brooding in various ways. Helmholtz, who was extremely prolific of high-grade hypotheses, explains: "So far as my experience goes, they never come at the desk or to a tired brain. They are usually apt to come to me when comfortably ascending woody hills in sunny weather. The smallest quantity of alcoholic drink seems to frighten them away."[15] The morning before a leisurely afternoon ramble in the country, however, he devoted to cramming his mind with all the pertinent knowledge he could assemble. It was during excursions away from habitual surroundings and without business cares or theoretical occupation that Sir William Hamilton and Henri Poincaré each solved a notable mathematical problem on which he had long labored in vain. Haydn said, "When my work does not advance, I retire into the oratory with my rosary and say an *Ave;* immediately ideas come to me."[16] The irregular lives of some artists afford varied opportunities for the incubation of original ideas.

Two facts contain warnings against depending too much upon inspiration. First, it does not come to those who are unprepared; it presupposes long and well-ordered reflection and researches consciously oriented toward a single end. Secondly, when the happy thought does occur, it is usually embryonic and amorphous, and in need of being shaped, clarified, and completed by rigorous methods.

10. Social Stimuli to Invention

Some of the most important and manageable conditions which favor discovery are social in character. Constructive thinking develops through the interaction and conflict of many minds, and in dependence upon the funded gifts of society: language, concepts, knowledges, and problems. Further, most discoveries are the cumulative achievements of numerous minds, often living in epochs far separated. Each individual gives some new and improved turn to the products of his predecessors. A textile expert once testified before the House of Lords that "present spinning machinery is supposed to be a compound of about eight hundred inventions."[17] The theory of evolution, the Gothic cathedral, and the American

14 Wallas, Graham, *The Art of Thought,* New York, Harcourt, Brace, 1926, p. 80.

15 Helmholtz, H. L. F., *Popular Scientific Lectures,* Vol. II, pp. 283–284.

16 Quoted by Sharnol, Thomas (pseud. of T. S. Knowlson), *Originality, A Popular Study of the Creative Mind,* London, Laurie, 1917, p. 87.

17 Kaempffert, W. B., "Systematic Invention," *Forum,* 1923, Vol. 70, p. 2116.

skyscraper are the products of prolonged movements involving the interplay of scores of creative minds:

> What could James Watt have effected in a tribe which no precursive genius had taught to smelt iron ore or to turn a lathe? Cromwell and Napoleon needed their revolutions, Grant his Civil War. Ajax gets no fame in a day of telescopic-sighted rifles.[18]

The preceding facts suggest several ways in which organized society may encourage invention. It is of first importance that freedom of discussion and criticism be guaranteed, and that new knowledge be promptly and widely disseminated. Liberty, leisure, and equipment, and, therefore, economic maintenance, are frequently indispensable for the growth of knowledge; and these the community can well afford to furnish, under certain conditions, to promising investigators. "Civilized society gets out of its men of talent, in any age, very much what it deserves to get — *i.e.* what in a proper way it asks for." [19] Especially should society promise and guarantee to the successful discoverer a genuine appreciation of his achievements. Among the needy wants of a needy age, few, if any, seem more pressing than that of the adequate encouragement and support of scientific research.

Society may also furnish in various ways opportunities for stimulating that coöperation among competent investigators which today is becoming a more and more important and necessary condition of progress in many fields. Pairs or groups of men possessing complementary abilities may work together to great advantage, as Bell and Watson did on the telephone; one surpassed in power to originate ideas, and the other was skilled in their practical realization. Nearly every invention passes through two stages, mental conception and physical embodiment, and many a man with fertile ideas never attains the second step because he does not ally himself with another person who has the technical skill, practicality, money, or something else which he lacks. Industrial laboratories are based on the recognition that the capitalist and the inventor both gain by joining forces at the beginning of an undertaking instead of at the end of it. In a similar way the patent lawyer and his inventor client may supplement each other's talents and achieve results that neither single-handed could attain.[20] No mortal mind can predict what marvelous achievements may come when great public problems are studied through long periods by coöperating

[18] James, *op. cit.*, p. 230; quoted with permission of Longmans, Green & Co.

[19] Royce, Josiah, "The Psychology of Invention," *Psychological Review,* 1898, Vol. V, p. 123.

[20] *Cf.* Potts, H. E., *Patents: Invention and Method,* London, Open Court, 1924.

experts who do not need to worry about making a livelihood, and who have within easy reach all available knowledge as well as adequate equipment and plenty of personal assistants.

11. Conclusion

The work of the discoverer, as described above, is marked by prodigious intellectual activity variously manifested. He is tenacious of the directing idea which shapes his inquiry, assiduous in searching the treasures of tradition, and vigilant in observation. He is prolific of questions, persistent in analysis, and aggressive and tireless in trying out new combinations of ideas. In spite of previous failures, he maintains patient self-reliance and enthusiasm to push on. An indispensable condition of discovery is this persevering will to search and research.

Just what particular union of factors and favorable conditions enumerated above may be efficacious in solving a given problem is obviously unpredictable. Most of these qualities exist to some extent in all minds, and certainly can be developed by effort and exercise. When all factors in full measure are combined in a single mind, they constitute the inventive faculty. One will search in vain for any specific and mysterious capacity in the make-up of the great discoverer. His superiority lies rather in a kind of exaltation or intensification of all those natural capacities which nearly everyone possesses in humbler degree. He will show more of finesse, more aptitude in seizing new relations, a more energetic and discriminating use of all his powers than the common man. Emerson declares in his essay on *Self-Reliance,* " In every work of genius we recognize our own rejected thoughts: they come back to us with a certain alienated majesty."

It is not surprising that the ancients classified inventors among the gods, for how uncommon, yet essentially man-like, are infinite pains and hard thinking. " Nothing is comparable," said Robert South, " to the pleasure of an active and prevailing thought — a thought prevailing over the difficulties and obscurities of the object, and refreshing the soul with new discoveries and images of things; and thereby extending the bounds of apprehension, and enlarging the territory of reason."

R. F. P.

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CHAPTER XV

STATISTICAL METHODS

I. Some Values of Statistics

An important recent advance in scientific procedure consists in the technical development and extensive use of statistical methods. Precise statistical ideas are gradually displacing prejudiced, hazy, and haphazard opinions concerning all sorts of intricate public questions. Statistical methods are one of the surest devices yet discovered for comprehending the unwieldy and uninstructive masses of facts which often confront us in our complex life. Some of their characteristics will appear as we proceed to summarize their values under three heads.

(*a*) First in order is *the descriptive function of statistics,* their power to show in quantitative terms what really makes up a mass of things. The informing worth of inventories and censuses is well known. Statistics were first limited to such information concerning states as might aid a statesman in apportioning taxes, land, and military service, and in similar administrative plans. Indeed, the name of the science is derived from *statista,* the Italian word for *statesman.*

Numerical summaries of population, agricultural and manufactured products, exports and imports, births and deaths, marriages and divorces, occupations, crimes, church members, etc., inform the mind with exact and compact pictures of vast ranges of data in which otherwise it would be lost. One acquires a marvelously comprehensive and definite view of what is going on in many fields of life by consulting statistical journals and great statistical summaries such as are found in the *British Annual Register, Whitaker's Almanack,* the *Statesman's Yearbook,* and the *Statistical Abstract* of the United States. Wonderful efficiency has been achieved in the collection and distribution of commercial statistics. For example, a dealer in a staple such as cotton may know every morning just how many bales came into market the previous day and what is to be the basic quotation on that day for transactions in every country on the globe. " Thus is the history of the world now written in figures, from day to day and from year to year. Statistics create an endless procession of moving photographs of the work and civilization of today." [1]

[1] North, S. N. D., " Seventy-five Years of Progress in Statistics," in *The History of Statistics* (John Koren, editor), p. 38; copyright 1918 by the Macmillan Company. Reprinted by permission.

(*b*) It is not, however, the absolute, but the comparative magnitude of statistical quantities which is of prime significance; namely, *their function of indicating the relative importance of groups,* of setting objects in a vast and illuminating perspective. This may be called *their explanatory value.* The art and the heart of statistical procedure consist largely in so arranging data that important comparisons may be made.

A few questions will suggest the possibilities of statistical comparison in revealing the tendencies and the causes of events. How does the number of births, deaths, divorces, or crimes vary in different regions, races, or periods? What changes are taking place in the proportion of rural to urban populations? of colored to white? of native to foreign-born? of low to high intelligence? What has been the trend in the prices and productions of various commodities in successive years? A fundamental question, then, in statistics, is, How does one body of facts change as compared with another which seems to be related to it? Most statistical methods explain ways of comparing, with mathematical precision, extensive groups of things.

(*c*) *The predictive use of statistics* is their supreme practical value. The statistician is the sibyl and the diviner of the twentieth century. While his judgments vary in probability, his tables are the surest horoscopes yet invented for reading the signs of the times. He has substituted scientific prognosis for rule-of-thumb guessing and occult premonitions, because his prophecies rest upon experience critically recorded, classified, and interpreted.

Statistics first helped statesmen to formulate useful programs, and then, in the age of geographical discovery, maritime insurance was founded upon a degree of regularity noticed in shipwrecks. Later, the computations of the noted astronomer, Edmund Halley (English, 1656–1742), concerning life expectation at each age became the basis of the first life-insurance institution, organized in London in 1698. At the present time

> an accumulation of data recording actual experience in a mass of selected cases enables the insurance actuary to calculate, with a certainty that approaches the miraculous, the average longevity of the insured, and to determine within a fraction of a fraction the average relation of each individual premium to the total outgo of his company.[2]

Thus statistical science has developed in the closest connection with the management of everyday affairs. Scores of activities other than insurance are now predetermined according to the measured expectancy of

[2] North, S. N. D., "Seventy-five Years of Progress in Statistics," in *The History of Statistics* (John Koren, editor), pp. 36 f.; copyright 1918 by the Macmillan Company. Reprinted by permission.

statistics. These activities are illustrated by adjustments to weather conditions, the buying and selling of goods, the fixing of tax rates, the admission of immigrants, the provision of school buildings, crop estimates, and the determination of railroad and steamship rates. At the present time there is a mad eagerness among business men to forecast statistically the prices of merchandise, or real estate, stocks, and bonds, and also to adjust intelligently their production and finances to predicted cycles of depression and prosperity. Thus, statistics is one of the most valuable compasses which science has produced for the guidance of human conduct.

2. Statistical Regularities

Trustworthy predictions depend upon carefully determined uniformities. Statistical laws and facts possess some striking characteristics. The facts seem arbitrary and fortuitous because their causes are complex, fluctuating, and often obscure. The presence of any natural order among them was long unsuspected. The discovery that regular tendencies exist is of fundamental importance in statistics.

The far-reaching significance of this principle was only gradually realized. As early as 1662 Captain John Graunt of London concluded that birth and death rates are quite constant, that thirteen girls are born to every fourteen boys, that a certain number of persons out of every hundred will die each succeeding year, and that the population of a country may be computed from the birth rate. L. A. J. Quételet (1796–1874), a prominent Belgian astronomer and mathematician, discovered a surprising and marked resemblance in the regularity with which phenomena occurred in such diverse fields as astronomy, meteorology, biology, and sociology. In each group of phenomena he noted that a certain mean or norm existed about which the number of occurrences or instances was great, and that as the distance from the mean increased, the number of items decreased with mathematical regularity. He found, for example, that suicides, crimes, and accidents show figures that are comparatively constant. S. N. D. North declares that statistics "has established the fact that in spite of all individual variations, the average or typical conduct of men operates with a high degree of regularity. The modern science of statistics is based upon this ascertained law." [3]

When the quantities representing the heights of men, the ages of horses, or the yield-per-acre of wheat are plotted, the curves look much alike, provided large numbers of data are considered. The geometrical

[3] North, S. N. D., "Seventy-five Years of Progress, in *The History of Statistics* (John Koren, editor), p. 18; copyright 1918 by the Macmillan Company. Reprinted by permission.

representation resembles the cross-section of a bell, or an inverted U with expanded legs which sprawl out more or less according to the range and number of exceptional instances included. This geometrical figure is called the *normal distribution curve.*

The normal frequency curve exhibits vividly the meaning of an average. If one takes a haphazard lot of samples from any group, he finds that the average of these samples closely approximates the average of the whole. This rule makes possible a tremendous economy in statistical inquiry, for a fairly accurate picture of a multitude of facts may be gained without the labor and cost of a complete enumeration, although such an enumeration is required for perfect exactness. Thus, " the anthropologist can discover the physical characteristics of a tribe or race by taking careful measurements of only a small minority of the whole. This principle is frequently denominated the *law of statistical regularity.*" It " states that a moderately large number of items chosen *at random* from among a very large group are almost surely, *on the average,* to have the characteristics of the larger group." [4] For example, in spite of false alarms and costly conflagrations, " the average annual loss for each fire in New York City mounts unfailingly to $680, and varies but $1.50 in two years."

Statistical regularities thus have a distinct character because of their peculiar relation to their supporting data. They hold good, roughly for individuals, precisely only for masses. The data are not thoroughly homogeneous, as are samples of water; they are not completely singular, as are the heroes of history; rather, they possess a *limited heterogeneity,* as do the wages of working men. Such data can be accurately averaged when enough samples are taken to compensate for individual variations and special influences.

Statistical methods are superfluous where phenomena are homogeneous and the influencing conditions few, as in the case of heavenly bodies or chemical reactions. Under these circumstances, generalizations may often be achieved through direct analysis aided by experimental isolation. Statistical methods are purposeless where singular influences predominate, as in the case of the great events and personages of history. *Statistical methods are indispensable in studying phenomena that are too involved for experimental control and too numerous for historical description, but which are classifiable and plentiful. Extensive sampling in statistics takes the place of intensive experimentation in other situations. Statistics is a general auxiliary science of wide usefulness.* It is *a method of wholesale observation* which elaborates enumerative induction and comparison.

[4] King, W. I., *The Elements of Statistical Method,* New York, pp. 28–29; copyright 1922 by the Macmillan Company. Reprinted by permission.

A *definition of statistics* is readily formulated from the preceding description. *In the singular it means the science which explains various special methods, chiefly mathematical, of measuring, collecting, classifying, comparing, and weighing masses of phenomena so as to find the laws of their development.* As used *in the plural,* the term comprises the carefully enumerated data and the results of the above methods. These results are commonly given a compact mathematical expression, such as totals, percentages, averages, index numbers, tables, and graphs, and are usually accompanied by explanatory statements. These exact and abbreviated forms greatly increase their clearness, utility, and convincing power. A few of the important phases of statistical methods will now be explained in a very preliminary way. Many excellent textbooks are available for a fuller study of the subject.

3. The Stages of Statistical Investigation

A statistical investigation commonly advances through four stages, as follows: (*a*) the setting of the problem; (*b*) the collection of the data; (*c*) the organization of the materials; and (*d*) the interpretation of results.

(*a*) The Setting of the Problem. — Every statistical inquiry must be thoroughly planned. Its purpose and procedure should be definitely formulated in advance so that the many forms and details may be suitably prepared. Special attention needs to be given to a clear definition of the primary units of measure or enumeration, in order that different observers can unmistakably identify, classify, and compare them. Overcrowding, for example, has been precisely defined as meaning " that the number of persons in a domicile is more than twice the number of rooms in it," excluding bathrooms, halls, pantries, and closets. The use of indefinite terms, such as accident, manufactory, farm, pauper, or unemployment, often vitiates the results of a whole investigation. Further, one's terms should be so adjusted to other investigations as to facilitate comparison with them.

Any interrogations that are needed should be as few and as simple as possible, so that informants can answer them easily, truthfully, and without antagonism or bias. Ideal questions are framed for such definite answers as " yes," " no," or a number, for these results are readily tabulated. Questions propounded in straw votes sometimes are weighted in favor of one's desired goal and do not admit of contradictory alternatives. Circulars and other blank forms employed should be drawn up in a convenient, economical, and orderly way. In general, the instruments required by an inquiry should be adapted to the mentality of those who are to make use of them.

In short, an investigation should be so pre-arranged that its goal may be realized with the minimum cost in errors and time.

(*b*) The Collection of Data. — Collecting and classifying relevant data is the second stage in the statistical process. Two kinds of sources may be distinguished. *Secondary sources,* that is, tabulated results of previous studies, are often available and may contain useful materials. These materials, however, must be critically examined and searched for errors, because statistics may easily have the form of excellence without its essence. Sound and specious results alike may have that show of accuracy and plausibility which neat, printed mathematical tables superficially present. By properly, or rather improperly, compiling figures to suit one's bias, one can make them prove almost anything. The statistician is constantly on his guard against the "illusions of accuracy," malobservations, and mistakes in calculation and interpretation.

Primary statistical data consist of the reports of first-hand enumeration, measurement, or estimates, such as those of census enumerators, factory foremen, school teachers, social workers, or special investigators. It is of fundamental importance that the primary observations be accurately made and recorded, for many errors in statistics are due to imperfect methods of collection.

The ideals of scientific observation are to be realized as far as possible in the collection of data. *The cardinal virtues of statistical enumeration are accuracy and absolute impartiality* in seeing and recording the facts as they exist. No bias of any kind should cause the observer to neglect, pass over, or distort relevant phenomena. He must neither select unrepresentative data to suit his preconceived opinion nor exclude unexpected or divergent facts, for they are often very significant. He is disqualified by having a political, financial, or other disturbing interest in the investigation. Often his competence depends upon some preliminary training in the technique of the inquiry. Courtesy, tact, and sincerity are other desirable qualities in an enumerator. In general, he must beware of the host of faults that commonly infect observation.

The problem of obtaining representative data becomes important wherever one's purpose does not, or cannot, demand complete enumeration. "Truth in its statistical aspect," declares G. P. Watkins, "is representativeness." *The principle for the scientific choice and testing of samples is*

> *that every unit in the district or class dealt with must have approximately the same chance of inclusion,* and that the selection must deliberately be made at random; compared with this rule the number of units contained in the selected sample is unimportant. The only test of the adequacy of the sample is the similarity of results obtained by random subdivision of the sample. To test the purity of London water needs the

examination of only a few microscopic quantities; to estimate the earnings of outworkers in West Ham would need a very extended inquiry before the accidents of the individual samples were eliminated.[5]

After collection, the *raw materials need to be edited* to insure as much accuracy, uniformity, and consistency as possible. *Suggestions of error* lie in data that are inconsistent, impossible, misplaced, too regular, or too irregular. Some errors, as in crop reports, are *compensating,* and, when taken in quantities, do not seriously affect the total. *Cumulative* errors may seriously modify results, and must be carefully guarded against. If, for instance, it is characteristic of women to understate their ages, a vast number of instances would not remedy the error.

(*c*) The Organization of Materials. — The third step in statistical procedure is the organization of the collected masses of materials. They are *classified, tabulated, and correlated* in those ways which promise most aid in comparison and interpretation. The process of reducing statistical data to logical order is called *tabulation.* Each table should have a clear title, studied purpose, and as concise, natural, and emphatic an outline as possible. Its captions and indentations, the variety and arrangement of its letters, lines, spacing, etc., should all facilitate the grasping of the logical interrelations of its parts. In short, *"comprehensiveness, comparability, and compactness" are the chief excellences of a statistical tabulation.*

The graphic presentation of statistical facts may properly follow their tabulation. The purpose of graphic representation is to aid the mind in quickly understanding the results obtained. The mind, with its narrow range of attention, cannot at once grasp the meaning of scores or hundreds of figures, even in a well constructed table. When they are plotted in geometrical forms, however, their comparative fluctuations can usually be comprehended at a glance.

Of the dozens of ingenious forms which have been invented for the graphic portrayal of statistical facts, one of the most valuable remains the simple curve. It is constructed by joining points that have been located on coördinate or rectilinear paper. Along the lines which serve as axes at the bottom and left of the field, numbers are written corresponding to the subclasses or definite units that are being coördinated. These numbers serve as points of reference for accurately placing every datum on the chart.

Suppose, for instance, that we wish to portray diagrammatically a table of mean monthly temperatures in a certain region for a given period. The segments along the horizontal or x-axis should be marked from left to right

[5] Bowley, A. L., quoted from Secrist, Horace, *Readings and Problems in Statistical Methods,* p. 155; copyright 1920 by the Macmillan Company. Reprinted by permission.

to represent months. Time here is the independent variable, which is always represented on the horizontal axis. Up the vertical or y-axis may be indicated temperature units of convenient size, for instance, of five degrees. Then every temperature datum may be indicated by a point placed opposite the proper degree and month. When these points are connected by a smoothed curve, the variations of temperature for a period of years may be grasped at a glance. In a similar way a multitude of other sets of statistical information may be set forth, such as the number of unemployed or divorces, or the exports or selling prices of some commodity.

The graphs described above have been called *historical graphs* because they exhibit data in their temporal relations. There are other problems of distribution in which duration is neglected, as when we ask how men may be grouped according to heights, wages, ages, or something else. Statistical answers to such questions may be arranged in a frequency table or plotted to form a *frequency curve.*

The *ratio chart* is commonly employed for accurately portraying relations irrespective of magnitude. It is valuable and necessary in comparing small and large units; for example, in studying fluctuations in butter and coal prices. The rise of a cent a pound for butter is not equivalent to a cent a ton for coal. In such cases the plotting of natural numbers would produce a disproportionate and incorrect appearance, whereas the use of a semi-logarithmic chart results in a correct picture, and includes also the natural numbers. The pie-diagram shows the proportions among the parts of a whole, as of government expenditures. Pictograms, bar charts, cartograms, and other diagrams are useful for special purposes. Cartograms are statistical maps in which frequencies are represented by varying shades of colors, density of cross-hatching, or dots.

(*d*) The Interpretation of Results. — The collection and organization of statistical data are long preliminary processes. The interpretation of the results is a short but requisite final one. It consists in critically generalizing upon and evaluating results. Comparison is the fundamental form of statistical interpretation. Indeed, *statistics may be defined as wholesale comparison reduced to exact and measurable forms by numerous tabular, diagrammatic, and mathematical devices.* Thus, averages enable us easily to compare groups that may differ widely in magnitude. Again, a curve representing coal production for a certain country may be readily compared with curves for the same period representing, for instance, the number of workers, or the selling prices of other commodities. Such comparisons as these often suggest instructive generalizations.

The many varieties of statistical comparison may be grouped into spatial and temporal comparisons, or their combination. In the first, one

investigates phenomena from the standpoint of their distribution in space, as one might study criminality by comparing its occurrence in rural and urban sections, in different races, climates, or political *régimes*. In temporal comparison one considers the relative frequency with which a certain phenomenon appears in different periods of time, as in the examination of seasonal unemployment, increase of height with age, weekly bank clearings, or cycles of business depression.

A verbal description concludes the statistical process. This should be written as briefly and lucidly as possible. It should include a concise account of the genesis and method of the whole inquiry, and an estimate of the degree of its accuracy. The totals, averages, trends, or other conclusions that are esteemed most important, should be pointed out and their significance epitomized in a way that will be free from all misunderstandings. Graphic methods are frequently of great aid in this exposition of results. Such common errors as mistakes in calculation, misleading diagrams, improper comparisons, and one-sided interpretations should be watched for. In short, this description should express one's best interpretation of the entire study. When this description has passed a final searching criticism and its literary form has been perfected, the investigation is complete. It is then ready for publication and application.

4. Averages

Averages or means are algebraic devices for thinking types. *An average is a single quantity which may fairly be said to stand for many other quantities of a similar kind.* It is a representative number in which the irregularities and accidents of individual components are equalized and submerged.

This mathematical device of averages has two general values: summarizing and comparative. First, it enables the mind in a single effort "to discern the dominant traits and the permanent modes" of large masses of facts. We are familiar with the informing power of an average that epitomizes the longevity, the income, or the height of numerous groups of persons. Secondly, averages make it possible for us to compare collections of very different size and often to reach thereby important conclusions. For example, one might compare the averages of the annual mortality during a certain period for many localities and obtain valuable information by seeking the causes which make some excessively low or high.

The reliability of averages is due to the principle of the inertia of large numbers: while individuals in a group constantly vary, the whole group changes very little The total population, the birth and death rates,

> average wages, change very little; similar quantities relating to a single family change very fast. It is this constancy of great numbers that makes statistical measurements possible.[6]

More than half a dozen *kinds of averages,* which serve different purposes, are in common use. Let us note the chief varieties. (*a*) The most familiar is the *arithmetical average* (commonly called also average or mean), which is obtained by adding a list of quantities of the same kind, and by dividing by their number.

(*b*) The *weighted mean* is obtained (1) by multiplying each quantity in a series by the number either of the individuals possessing this quantity, or of the points of weight assigned to it; and (2) by dividing the sum of these products by the total number of individuals or points. Let us suppose that a student has earned 60, 75, and 90 per cent in three examinations of 10, 50, and 100 minutes. The arithmetical mean of 75 would be unfair because of the differences in time periods, but the weighted average will furnish a just estimate. This is obtained by multiplying the three grades by 1, 5, and 10 respectively, where the first is taken as the comparative unit of weight. The sum of the products is then divided by 16, the sum of the weights assigned. Such a cumbersome grading system becomes greatly simplified by dealing directly with weights assigned to each exercise. The weighted average has been of great service in calculating the cost of living where the several items in the family budget differ widely in importance.

(*c*) The *mode* is the quantity which occurs with the greatest frequency in any group of similars. It is the vogue, the most common occurrence, or the type that is most numerous among other sub-types. This kind of mean corresponds most exactly with the popular idea of average as applied, for instance, to living conditions, sizes or shapes of articles of clothing, intelligence, or income. It is uninfluenced by extreme cases and is determinable from well chosen samples. After the data have been classified according to their frequency, the mode, as a rule, is readily determined by inspection. When facts are concentrated around more than one class value, the distribution is called multimodal.

(*d*) When the members of a group are arranged according to magnitude, the point on either side of which there are an equal number of cases is called the *median.* When the number of items is even, the median value is midway between the two middlemost quantities. Both median and mode have the advantage of being unaffected by exceptional cases.

The mean, the mode, and the median may differ much from one an-

[6] Bowley, A. L., *Elements of Statistics* (ed. 4), New York, Scribner, 1920, p. 8; quoted with permission of publishers.

other. In the United States mortality tables for 1910, based upon 100,000 cases, the modish or most fashionable age at which to die is 74.0 for white males and 73.5 for white females. The corresponding medians are 59.30 and 63.27 respectively; while the weighted means are 50.23 and 53.62. The means for negro males and females are 34.05 and 37.67 respectively. The means here represent the " expectation of life " at the time of birth or zero age. " ' The expectation of life ' means the average number of years that persons of a given age will probably survive." [7]

The reliability of an average depends upon the extent to which the quantities of the group diverge from the central tendency which it represents. To determine the degree of such variations very precise " measures of dispersion " have been invented. The principle involved in these will be evident from noting the steps in calculating what is called the average deviation. First, one finds the difference between a selected kind of average and every quantity in the group, taking all signs or values as positive; next, one adds these differences together; and, finally, one divides this sum by the total number of original items. The result is helpful in judging of the degree of representativeness possessed by the mean in question. Thus, 15 might be the average of 14 and 16, of 10 and 20, or of 1 and 29. The smaller the average deviation, the more exactly does the mean typify the separate quantities involved. Relative deviations are evidently much more important for comparative purposes than absolute ones.

The mean deviation also indicates the degree of error or accuracy which is likely to be present in making guesses as to the position of future members. An important part of statistics, upon which we cannot elaborate here, consists of methods of measuring the degree of error which may be present in statistical results. Since we cannot altogether eliminate errors from our observations and reasonings, the only scientific procedure is to study and measure them as precisely as possible.

5. Correlation

Modern methods of correlation have given a new precision and power to the handling of masses of loosely connected phenomena. Statistical methods generally apply, as pointed out earlier, where effects cannot be traced to simple causes by direct analysis. In all phases of our complex life, phenomena appear which affect and are affected by numerous factors no one of which is sufficient, in itself, to produce the result, and which may be more or less independent among themselves. For example, a dozen influences could be suggested which, in various combinations, are responsible for students getting high grades in their courses. Correlation is a means of

[7] Reprinted by permission from *Vital Statistics* by the late George C. Whipple. Published by John Wiley & Sons, Inc.

measuring exactly the proportion of influence that each component exerts. It supplies, in short, "*a precise knowledge of the degree of association or contingency between different events or characters within a group.*" By assuming that there is a widespread, if not universal, contingency of varying degrees among the phenomena of the universe, we obtain a fruitful principle of discovery for a multitude of promising hypotheses in the study of any event.

Two phenomena or quantities are said to be correlated when the fluctuations in one are in positive or negative sympathy, to some extent at least, with the fluctuations of the other. The mathematical result is fittingly expressed in the form of a ratio; namely, as a percentage expressing the share that one of several contributing influences has in producing a certain effect. It must, of course, be carefully determined by induction from an adequate number of instances.

It is always safe to think of *correlation as a degree of association,* and thereby avoid the fallacy of covariation. This consists in assuming that two covarying series are causally connected when in fact they are both products of a common third set of causes. The prices of wheat and of steel, for instance, might show mutual fluctuations due to certain general business or political conditions and not to any interaction between themselves. Again, if we had much ingenuity and little common sense we might correlate the rapidly increasing number of college students with the growing use of automobiles, or the spread of cancer with the increasing consumption of bananas.

The meaning of *several types of correlation* will now be described. Let us suppose the impossible; namely, that the grades of students are in direct ratio to the number of hours of preparation. Under these circumstances, a small amount of time spent in study would bring a low grade, and so forth. If the grades of such a utopian group were plotted with reference to their corresponding hours of study, the points would fall so as to approximate a straight line roughly bisecting the angle of the axes of the chart. Correlation is measured mathematically by determining the degree to which data diverge from a central line or curve. The algebraic calculation involved is too complex to be explained here, but if applied to this case, would yield a *coefficient of correlation* (usually symbolized by r) approximating $+1.00$.

The mathematical technique of correlation is designed to bring all possible coefficients within the extremes of $+1.00$ and -1.00 (also written $+100$ and -100). A *$+1.00$ correlation* between groups of variables A and B means in general that when they are reduced to comparable terms, they are associated in equal quantities; that is, large quantities of A are associated with comparably large quantities of B. Thus $+.80$ is con-

sidered a high coefficient of positive correlation; it is, in fact, the correlation between a man's stature and his cubit (the distance from the elbow to the tip of the middle finger).

On the other hand, *a correlation of — 1.00* means that when *A* and *B* are reduced to comparable terms, the mutual relation is perfect, but is reversed from the positive one; that is, large quantities of *A* are associated with small quantities of *B,* and vice versa. For example, a perfect negative correlation exists between the gravitational attraction of two bodies and the distance between their centers. When data having such a relation are plotted, the points also approximate a straight line, but it lies in a position that is roughly at right angles to the position of the line representing a +1.00 correlation. In short, a positive correlation between two variables means that an increasing value of one corresponds with an increasing value of the other. A negative correlation signifies that the diminishing value of one variable corresponds with the increasing value of another.

As the positive and negative coefficients of correlation decrease and move away from these ideal limits already defined, the distribution of the plotted points becomes more and more scattering and irregular, until the limit of diffusion, dissociation, and irrelevance is reached. This condition is represented by 0 (zero) coefficient, which means a chance relationship. It signifies that *any* quantity of *A* is likely to be associated with *any* quantity of *B,* and vice versa.

Zero or chance correlation is to be carefully distinguished from negative correlation. *Zero correlation means that for an increasing or diminishing value of one variable, a second variable shows no corresponding change whatever.* Since correlation values range from +1.00 to — 1.00 and the numerical expressions of probability from 1 to 0, a 0 correlation correponds to a probability of ½; a correlation of —.50 is equivalent to a probability of ¼; and a correlation of +.75 means a probability of ⅞.

One would expect to obtain approximately a zero correlation between the heights and grades of students. Here, and indeed everywhere, one must be exceedingly cautious about affirming complete independence without verification. Sociologists have found, for example, that great men as a matter of fact are somewhat taller on an average than other persons. In other words, among many familiar phenomena there is some degree of correlation which the uninquiring man would never suspect.

6. The Measurement of Probability

Prediction is indispensable for that control of events at which science aims. The certainty of prediction is no greater than the degree of

probability possessed by the laws, correlation coefficients, averages, or other concepts from which it is deduced. Our discussion here will be limited to a brief indication of some statistical methods of calculating probability.

In the measurement of probability we have the means of appreciating the relative value of a series of observations. The last French census of the eighteenth century was calculated from the number of births as determined for some districts. After counting in these both the number of inhabitants and the number of annual births, an average number of inhabitants corresponding to the number of births was obtained. Then, to obtain the total population of other districts in the kingdom, one needed only to multiply the annual number of births by this coefficient.[8]

P. S. Laplace (French, 1749–1827) developed the principles involved in this procedure, and gave it a rigorous determination in the form of the fraction $p/p + q$. The fundamental principle involved is that the probability or chance, P, that any phenomenon will happen is expressed by a fraction whose numerator is the number of the favorable occurrences of the phenomenon p, and the denominator the total number of possibilities or alternatives (occurrences p plus failures to occur, called q). Instances are said to be favorable when they possess the properties which are required by the problem.

It is evident that when q is small and p increasingly large, P approaches 1, or unity, the symbol of complete certainty, and one limit of probability. The other limit, that of impossibility, is represented by zero. The fraction approaches zero as q becomes proportionately large. One has to exercise the highest discrimination and good sense so as not to allow q to increase improperly by the inclusion of any irrelevant event. In everyday life, if the value of the fraction $p/p + q$ for any event is greater than 50%, the event is said to be probable; if it is less, it is regarded as improbable. In statistical science, however, anything above 0 indicates a degree of probability.

If, then, the probability of an event is 0, the event cannot happen; if it is 1, the event is certain to happen. In the common judgments of daily life probability is the rule and certainty the exception. Most of our life is lived in that sphere of adventure which lies between the extremes of ignorance and sureness. There is no need of calculation where our knowledge is complete and definite; and where our ignorance is complete, there is no basis for it other than what is warranted by the principle of excluded middle. In mathematical terms this principle may be expressed by ½. In other words, in a state of initial ignorance, there are equal chances that a possible event, or connection of events, will occur.

[8] March, L., "Statistique" in *De la Méthode dans les sciences* (2d series), Paris, Alcan, 1919, p. 322.

This fraction of ½ is readily derived from the formula mentioned above by letting p represent the possible occurrence and q the possible nonoccurrence of the hypothetical event. By substitution, likewise, we readily perceive that the chance of a head turning up in tossing a coin is ½, for there is no reason to suppose one side is more likely to be thrown up than the other. In the case of a die with six faces, any one of which may be thrown uppermost, the probability is 1/6 because in this case q is 5, the number of unfavorable faces which is present at each throw.

The general rule, then, in calculating probability is that if an event can happen in p ways and fail to happen in q ways, the probability or chance of its happening is $p/p + q$. To Laplace belongs the credit of having suggested this influential formula. If 1 is certainty and P the probability that a phenomenon will happen, $1 - P$ evidently is the chance that it will fail to happen. In other words, the improbability of an event is $q/q + p$. *Probability,* therefore, *may be defined in statistics as the index of proportional frequency with which an event may be expected to occur.*

In conclusion, *a few methods of determining probability* under more complicated circumstances may be noted. Let us consider first *the combined occurrence of two events.* Let a and b represent the respective probabilities of the independent events A and B. Events are called independent when the occurrence of one of them neither increases nor diminishes the probability of the other. Then the probability that *both A and B will happen,* that is, occur together or in succession, is $a \times b$. Thus, since there are 4 kings in a full pack of 52 playing cards, the chance of drawing a king is 1/13; that of drawing a red card is ½. The chance, therefore, of drawing a red king is $1/13 \times ½ = 1/26$. The chance of throwing three heads in succession in tossing a coin in the product of their separate probabilities; namely, $½ \times ½ \times ½ = ⅛$.

When events A and B both may happen, we multiply, as we have seen, *their separate probabilities* $(a \times b)$. On the other hand, *when either may happen, we add their separate probabilities* $(a + b)$, *provided* the events are so related that if either happens, the other cannot happen. In tossing a coin, for instance, it is obvious that the chances that either heads or tails will appear is ½ + ½, which is 1, or certainty. In the case of a die, the probability of throwing either 4 or 5 in a single trial is the sum of their separate chances; namely, $1/6 + 1/6 = 1/3$. If we complete the original formula, it is clear that in this case p is 2, for both 4 and 5 are considered favorable occurrences; and q, therefore, is 4, the remainder of possibilities; the result is $2/(2 + 4) = 1/3$. Statisticians have developed formulas for other and more complicated combinations which we cannot consider here.

We have had above a glimpse of the powerful methods of statistics, which are proving more and more fruitful in an increasing number of fields.

They make possible a new and important era of exact and comprehensive thinking, predicting, and planning in commercial, governmental, and other social relationships. They represent one of the latest and most brilliant achievements of science in reducing qualitative notions to manageable quantitative form. Their promise of service in solving and interpreting the problems of the future, especially the intricate problems of social life, is very great. "The science of statistics is the chief instrumentality through which the progress of civilization is now measured, and by which its development hereafter will be largely controlled."[9]

R. F. P.

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[9] North, *op. cit.,* p. 15; copyright 1918 by the Macmillan Company. Reprinted by permission.

CHAPTER XVI

THE ORGANIZATION OF KNOWLEDGE

1. The Values and the Nature of System

All phases of scientific investigation culminate in the systematic organization of knowledge. The theoretical goal of the scientist is an articulate, true, and coherent grasp of his subject-matter. Organization consists in adjusting diverse elements according to their mutual relationships or according to some desired end.

The numerous values of systematization arise from the unified structure by which a system holds together a more or less wide range of varied facts. Good order is necessary for clear and economical thinking as well as for lucid exposition. Organization also is indispensable in making the vast accumulations of modern knowledge convenient and available for useful public appropriation. Further, the systematizing of knowledge provides novel perspectives from which to judge of the bearings and significance of its components. This fact is illustrated by the sweeping insight attained at a few strokes of thought in reviewing the periodic table of chemical elements. This same scheme is a famous instance of how the integration of knowledge may bring to light new relationships, solve old problems, and challenge fresh discoveries. Thus convenience, love of order, and practical necessity all contribute to driving science into more and more systematic form.

The scientific system is the most characteristic product of logical thinking. Whatever its objective ground, we know it as a coördinated chain of inferences, as a set of judgments bound together by the thread of common terms. It is by the shuttle of inference that the woof of reason and the warp of reality are woven into the great tapestries of scientific knowledge.

A system is a complex and consistent whole of mutually related facts or elements. Some examples of systems are the solar system, the postal service, a mammal, a drama, or a geometry. Unlike an aggregate or collection, a system is integrated by some principle of order. It implies that intellectual method has been successfully applied. Bosanquet's definition is an excellent one: " A system means a group of relations or properties or things so held together by a common nature that you can judge from some

of them what the others must be."[1] The mutual responsiveness of the parts of a system varies greatly in strength; some systems are very loose while others are compact.

2. Kinds of Systems

Systems also vary immensely in their complexity. They range from the simplest concept of a child to the cosmic philosophy of a Spencer or Hegel. Any one of a multitude of ideas may serve as the originating and unifying principle of a system. Systems themselves may be divided into three overlapping types according to the three basic interests (theoretical, practical, and esthetic — knowing, doing, and creating) which may operate as centers of gravity in the designing of systems. For example, a system of chemistry or geology is designed to give knowledge; an automobile factory produces useful vehicles; a symphony is a creation which may stimulate esthetic enjoyment.

(*a*) *A theoretical or scientific system is meant to correlate concepts or propositions in a valid and illuminating way.* It is the form of truth in which consistent reasoning finds most perfect expression. *There are three kinds of theoretical systems: the conceptual, the classificatory, and the demonstrative.* The first defines an individual object, the second organizes resemblant classes, and the third exhibits necessary relations between laws or propositions.

1. *A conceptual or formal system* is the clear idea we may form of an individual object. A concept is a product of definition, which in science may be a long and laborious process. Thus the biologist's idea of a frog, the physicist's conception of an atom, or an historian's notion of Napoleon the Great is the articulate consummation of much tedious analysis and synthesis.

2. A *classificatory system* is illustrated by Mendeléeff's periodic table of chemical elements, by Linnaeus' classification of plants and animals, or by Humboldt's geography. We shall return below to the problems of classification.

3. A *demonstrative system* may be otherwise named a deductive, implicative, or logical system. It is illustrated by a system of mechanics, of geometry, or of symbolic logic. Less perfect examples are found in any developed dogmatic theology, such as scholastic or Mohammedan theology. The dominating idea of this type of intellectual organization is *proof;* namely, of showing how certain propositions necessarily follow from others. Its logical beginning is a set of definite postulates, laws, or dogmas, and its procedure is deductive. It is the ideal logical form in which a body of

[1] Bosanquet, Bernard, *Essentials of Logic,* p. 140; copyright 1920 by the Macmillan Company. Reprinted by permission.

scientific knowledge may be integrated when it has reached an advanced stage of development.

Above all other theoretical systems in comprehensiveness stands the metaphysical system. In this form the philosopher sets forth the results of his endeavors to understand life and the cosmos as a whole.

(*b*) A *practical system* is any set of machines, forces, or persons so correlated and regulated as to realize some useful end. A printing press, a banking house, a railroad system, and a government are examples. The formation of a practical system presupposes both the intelligent choice of some end and the selection and adjustment of fitting means for attaining that end.

(*c*) Any satisfying work of art, whether a cathedral, a novel, a piece of sculpture, or a symphony, illustrates what is meant by an *esthetic system.* It is a diversity in unity, created by selecting and composing elements to form a satisfying harmony. The parts of a painting or a temple may be so delicately adjusted and balanced that an omission or change in a single detail would require a rearrangement of the whole. A successful drama or epic poem is a triumph in organization. It brings together a multitude of persons and events, of sounds, feelings, and metaphors, and so disposes them as to produce a unified *ensemble.*

Thus, *the consistency of truth, the adaptability of practice, and the harmony of art are the variant forms in which our love of rational order and unity realizes itself* as different powerful interests come to dominate its expression. As typical representatives of the three kinds of systems discussed we may mention the scientist and philosopher, the engineer and business executive, and the musician and dramatist. The three types of system overlap and blend in varying degrees.

3. The Nature and Kinds of Classification

Let us proceed now to examine more fully the nature and rules of classification. Classification is a daily and universal logical process. We classify everything and everybody, and could not think without doing so. When we say that Trinity Church in Boston is Romanesque, or that this dog is a foxhound, we perform simple acts of classification. *Classification in general means any orderly grouping of objects which exhibits their mutual relationships.* It is usually concerned with likenesses and differences, and the proper subordination of classes. It is the organizing culmination of extensive comparison.

It is clear that objects may be classified in as many ways as they have properties or relationships which are considered worth distinguishing. Most scientific classifications are based upon the natural order of things, and are,

therefore, called natural classifications. An *artificial classification* is based upon some superficial or accidental characteristic which is arbitrarily chosen or assigned to a class of objects. For example, the classification of the letters of the Roman alphabet according to their shape would be artificial; the division of them into gutturals, palatals, dentals, and labials is a natural classification because, by telling us how they are pronounced, it informs us concerning a fundamental property of letters.

Two important and common kinds of artificial classification are alphabetical series of names and arithmetical arrangements of objects according to assigned numbers. Both of these classifications have well known practical purposes. The alphabetical arrangement is valuable, for example, in indexes, card catalogues, and city directories. The arithmetical classification is useful, for instance, in numbering houses or automobiles, prisoners or soldiers. In contrast with the artificial alphabetical arrangement of words in a dictionary stands the remarkable classification of words according to their meaning which is found in Roget's *International Thesaurus of English Words and Phrases*.[2] This is an indispensable book of reference for every careful composer.

We return now to the discussion of natural classification. *A natural classification is an ordering or assorting of objects according to some essential property.* We shall discuss three of the most important properties which objects may have: position in space, position in time, and quality.

In *geometrical classification* objects are arranged according to their position in space. It is based on the fact that every particle in the universe at any instant has a definite geometrical position with reference to every other. Its most common form is geography, which describes continents, seas, and rivers, nations, cities, and farms, minerals, plants, and animals according to their location on the surface of the earth. The descriptive astronomer seeks to determine the position of the stars in the heavens. Our cities are laid out more or less systematically, and our households are made according to plan. It is as if we could not feel at home in the world until we knew it in every nook and corner.

Classifications of events according to their places in the time series give rise to *historical and evolutionary systems.* We shall discuss these below in a separate section.

Classification in the narrow sense commonly means the tabulation of things by reference to their *qualities. It may be defined as the arrangement of the objects in a universe of discourse into species and sub-species according to their similarities and differences.* This kind of classification is properly called subsumptive because it consists in separating a given aggregate into its kinds or sub-types. The resulting plan or hierarchy is called a sched-

[2] Revised by Mawson, C. O. S., New York, Crowell, 1924.

ule or table of classification, and its parts are named main division, subdivision, and section.

Examples of qualitative classification may be found in any exact science. A beautiful illustration is the grouping of minerals according to their crystalline structure. The grand hierarchy of living things is suggested by the scheme of biological classification in Table VIII following.

TABLE VIII. SCHEME OF BIOLOGICAL CLASSIFICATION

Subordination	*Examples*	*Differentiae*
Realm of life	Organisms	Bodies made of cells containing protoplasm
Kingdom	Animals	Organisms with sensibility and motion
Phylum	*Chordata*	Animals with skeletal axis and gill slits
Subphylum	*Vertebrata*	Animals with backbones
Class	*Mammalia*	Hairy animals the females of which suckle their young
Order	*Carnivora*	Flesh-eating animals
Family	*Canidae*	Carnivorous animals with claws not retractile
Genus	*Canis*	Dogs and wolves with round pupils
Species	[*Canis*] *familiaris*	Domestic dogs
Varieties	Hounds	Dogs which track game by scent
Individuals	This bloodhound	Owned by Mr. Lomar

Other divisions from class to species may also have subdivisions, as does phylum in this case. According to the universal binomial system, any organism is designated by a Latin noun which names its genus and a Latin adjective which indicates its species, as *Canis familiaris*. A third adjective is sometimes added to mark a sub-species or variety. Each science develops a nomenclature which is suitable to the classifications which it achieves. The most comprehensive of all classifications is the classification of the sciences themselves. This is essentially a philosophical problem and will be discussed below.

4. The Technique of Classification

A number of technical terms have grown up in logic in connection with classification. The group of individuals to be divided is called leading class or a *genus* (plural, *genera;* adjective, *generic*). *A class is a plurality of terms characterized by the same predicate or universal.* As soon as we specify a condition or predicate, that predicate constitutes a class of objects which have it, in contrast with a class of objects which do not have it. We think of a genus as a class of objects which is, or may be, made up of subordinate classes.

These subdivisions of a larger class are called *species* (plural, *species;* adjective, *specific*). We think of a species as a class of things which is part of a larger or superordinate class. Thus oranges, limes, and citrons logically are species of citrus fruits. A species has at least one more property than a genus to which it belongs. The orange, for example, has a specific flavor which no other citrus fruits possess, and which cannot, therefore, be ascribed to citrus fruit in general. In biology, *genus* and *species* are absolute: they always refer to the same group of organisms. In logic these terms are relative: the same class may be both genus and species in different connections. Thus, poetry is a species with reference to fine art but a genus with reference to the lyric. The operation of arranging the members of a class according to their species is called *division.*

A *property* in the technical sense means a quality belonging to *all* the members of a genus. On the other hand, an *accident* is a chance attribute; it may be predicated of *some* members of a class but not of all. *Differentia* (plural, *differentiae;* adjective, *differential*) is any attribute which is added to a genus to constitute a species; in other words, it is any mark which distinguishes coördinate species. For example, a coffin-screw differs from all other screws in the one respect that its head is so cut that it can be turned only one way.

The following rules are valuable guides or ideals in obtaining good classifications or divisions. (*a*) *A division should be based upon a single principle or characteristic which is applicable to the aggregate to be divided.* When more than one principle is employed, the *fallacy of cross division* or overlapping usually results. This error would occur, for example, if we classified books as prose, poetry, history, science, and romance.

The principle of division should be as natural and fundamental as possible, and should be suited to realize the end in view. The same objects may be grouped in different ways for different purposes. A bookbinder might classify books according to the binding material; a traveler, according to some geographical plan; and a philologist, according to language.

The deliberate use of a twofold principle of division is justified in those

rare cases where we wish to study the effect of combined characters. For example, in our study of categorical propositions, after dividing them into two kinds according to quantity, and again into two kinds according to quality, we combined the principles of quantity and quality and derived four types.

(*b*) *The species into which a genus is divided should be mutually exclusive.* This rule is really a corollary of the first, since overlapping is usually due to the presence of more than one principle of division. This rule is observed when we divide triangles into equilateral, isosceles, and scalene. The ideal stated in this rule can be only approximately or arbitrarily realized where species are so much alike that they shade off into one another. This is the case, for example, in the classification of substances into gases, liquids, and solids, of winds into twelve velocities, or of stars into twenty or more magnitudes. Species which exhibit slight divergencies may often be arranged in an evolutionary scale.

(*c*) *A division should proceed by gradual or progressive steps.* A genus should be divided into its immediate or proximate species before subspecies are distinguished. In the tree of Porphyry, for example, animate beings are divided into sensitive and insensitive before sensitive beings are divided into rational and irrational. In such an orderly descent, the lowest species is reached *step by step.* One commences with terms of wide denotation and small connotation, and proceeds to terms of narrower denotation and greater connotation.

(*d*) Finally, *the species into which a genus is divided should be collectively exhaustive.* The sum of the constituent species is to be coextensive with the genus divided. Everything relevant and nothing irrelevant should be included. For instance, an income-tax law can be justly administered only if every form of income is included in the schedule. Violations of the third and fourth rules produce *fallacies of incomplete classification.*

The chief points in the four rules of division may be summarized thus: *Every step in a division must be based on a single useful principle which is applicable to all members; the resulting species should be mutually exclusive and collectively exhaustive.*

5. Evolutionary Method

When one class of objects metamorphoses into another, we cannot classify them in the same way as before. We do not change our concepts but we arrange the objects in an historical order. For example, a regiment of recruits and a regiment of trained troops may be made up of the same individuals, but they have undergone a change which we call evolutionary.

Historical and evolutionary systems are so important in civil and scientific affairs that they deserve special treatment.

The historian is not satisfied with mere chronicles or annals, but wishes to ascertain the whole context which produces a given character or civilization. He organizes his results in that combination of chronological, geographical, and causal ideas which we call an *historical system.* It is illustrated by the story of the Russian Revolution, or, more simply, by a biography of George Washington. The same kind of system is found also in the set of correlated facts which a lawyer endeavors to construct in a criminal trial.

Historical method attains most perfect form in *evolutionary classification.* To the methods of history this *adds extensive comparison. Evolutionary classification consists in transforming a collection of similars into a genealogical tree.* Classes of individuals which are more or less alike are arranged, where possible, as successive stages in an ascending or descending line of development. In this way isolated individuals may become significant links in a continuous chain. One receives a deep impression of the illuminating power of evolutionary classification when one views in an anthropological museum hundreds of Stone-Age implements graduated according to fineness of workmanship.

To use the method of evolution means to inquire whether or not a given collection of somewhat similar facts may be so arranged as to form phases or stages of a continuous development. This viewpoint in investigation is also called the *genetic method.* It is the endeavor to ascertain how something originates from what precedes and influences what follows. The great classic of evolutionary method is *The Origin of Species* (1859) of Charles Darwin.

The method of evolution has extensive applications outside of biological science. The scientist does not impose evolutionary order upon any facts which do not admit of it. Rather, this method provides the scientist with a fruitful *point of view for questioning* a great variety of phenomena where he suspects, but does not know, that orderly development exists. It may be tried out not only on the structures and functions of living organisms, but also on languages, institutions, and ideals, chemical elements, mountain ranges, and stars, and on hosts of other phenomena. Indeed the idea of evolution has influenced all the sciences, forcing us to think of everything as having a history behind it.

The several varieties of systems which have been described in this chapter may be summarized in the table on the opposite page:

Table IX. Kinds of System

				Examples:
Theoretical	Conceptual			
	Classificatory	Artificial	Alphabetical:	Dictionary
			Arithmetical:	Automobile numbers
		Natural	Geometrical:	Geography
			Qualitative:	Crystallography
			Historical or evolutionary:	Biological evolution
	Demonstrative			
Practical				
Esthetic				

6. Explanation

It is often truly said that the goal of a science is a full explanation of the phenomena which fall within its purview. *To explain anything we do not understand is to see or to show how it fits into some order or system of things which we do understand or know.* Thus, a broken window is explained by connecting it with a system which includes also a baseball in a corner of the room, a nearby vacant lot, and a gang of boys at play. We really do not understand one thing well until we know its relations to many other things.

The order of explanation is the reverse of the order of research. Thinking as problem-solving looks and moves forward; thinking as explanation looks backward and takes cognizance of the solution obtained. *It consists in reviewing an inference from the standpoint of the conclusion reached* for the purpose of discerning how the conclusion illuminates the facts or premises from which it flows. In this way an original inductive inference becomes a deductive one in explanation. For example, concept-making induction makes possible subsumptive deduction, which in turn yields explanation by classification. If I know the characteristics of electricity, I may be able to recognize them in lightning and thus explain lightning. Again, law-making induction makes possible hypothetical deduction, which in turn yields causal explanation. Explanation, then, is primarily deductive, since it solves an enigma by referring it to some higher principle or system which is known. It is a *function of inference,* and the types of explanation may be correlated with whatever types of inference we recognize. We shall not elaborate this hypothesis of correlation, but turn to a brief description of the common kinds of explanation.

(*a*) *Quantitative and statistical explanations* answer questions in terms of number. Such answers are very important in an age of statistics and exact measurements. We like to know how old, tall, heavy, or rich certain

persons are. The geodesist helps us to understand the earth by telling us its circumference and diameter, and the astronomer, by determining its distance from the sun and its velocities. The chemist explains a chemical compound in part by ascertaining the precise quantitative proportions of the several elements which compose it. Only numbers will satisfactorily answer a host of questions we ask.

(*b*) *Causal or mechanical explanation* is of paramount importance in science. A scientist usually believes that he has explained a fact when he has determined its causes. A fact is causally explained when we can refer it to some law or set of conditions according to which it is produced. For example, the blueness of the sky is explained by the principle of reflection: air molecules scatter sunlight, but scatter the shorter blue rays more strongly than the red. Again, since white light can exist only when all primary colors are blended together, the removal of blue light leaves the rays from the setting sun reddish in color.

(*c*) *Historical and evolutionary explanations* are more complicated forms of causal explanation. They may not only tell us *how a fact came to be what it is,* but they may also enable us to grasp the direction of its development. Thus, a fossil is historically explained when it can be linked in a series with others to constitute an evolutionary scale. To say that a dome is an oven or a tent and a fluted column a tree trunk is to suggest illuminating origins. Again, we can explain the sting of the female bee as an adaptation of a probing instrument once used for depositing eggs. These types of explanation are too familiar to need further exposition.

(*d*) *Classificatory or subsumptive explanation* is familiar and common. A fact is explained by this method when it has been successfully identified as a member of a known class. A botanist explains a plant by analyzing it and fitting it into his table of classification. Again, much light has recently been thrown upon the construction of Greek vases by referring them all to a relatively small number of geometrical figures. We wish we could explain Paul's " thorn in the flesh " by classifying it. A lawyer often takes the greatest step in solving a case when he finds exactly the laws and judicial decisions which cover it.

It will be observed that the essence of *logical definition* is classificatory explanation, for it consists in referring a term to its proximate genus and in stating its differentia. Thus we define and explain a cone as a pyramid with an infinite number of sides.

When classificatory explanation is reversed, we obtain what may be called *explanation by illustration.* In this case we start with an abstract principle and endeavor to understand it by seeing how it is embodied in particular examples. This kind of explanation is common in those homiletical discourses in which a text is expounded by a series of illustrations. We

are employing the same method in this section to explain the several kinds of explanation.

(*e*) *Teleological Explanation.* — The four types of explanation so far discussed are illustrated by the following questions about a tree: How big is it? What are the conditions of its growth? What is its remote ancestry? To what genus does it belong by reason of its structure? We may go on to ask: What are its wood and fruit good for? Is it ugly or beautiful in form? Here we pass from questions of cause and kind to questions of worth, function, or purpose.

Teleological explanation consists in estimating how far a given activity or object realizes some fitting purpose or value.[3] Thus, we might evaluate the adaptation of flowers to pollen-carrying insects, or the efficiency of a machine with reference to its proper end. A typewriter may be mechanically perfect and yet be quite worthless for our purposes because its characters are Russian. We call a work of art beautiful, or a human act virtuous, or an argument valid, when each of these things realizes in a satisfying way the appropriate values according to which we judge them.

Purpose is an especially important mode of explanation wherever human activities and institutions are concerned. Our thinking takes teleological form when we seek to understand the stages of anything in the light of the end towards which it is developing. *We interpret certain stages as means through which a valued goal is obtained.* The existence of such a goal, however, requires a unitary and abiding agent which is capable of sustaining itself and its purpose through the course of its developing activities. *Teleological explanation presupposes intelligent agents and systems of values which these agents seek to realize.* Causality is thus elevated from the mechanical plane to the level of intelligent and volitional activity.

But personal agents and judgments of value are characteristic terms of philosophical explanation. The modern scientist usually regards them as beyond his proper province. He commits himself to a mechanical explanation from which purposive factors are ruled out by postulation. This exclusion is useful as a method of study which is limited in its scope. It is often equally fruitful to assume purpose as a category of explanation; indeed, this assumption is necessary for a complete explanation of human life and its products.

Mechanism and teleology, however, are supplementary rather than antithetical. "Mechanism without teleology is the play with Hamlet left out; teleology without mechanism is Hamlet with the play left out."[4]

[3] On the teleological judgment see Goblot, E., *Traité de logique,* Paris, Colin, 1918, Ch. XV to XVII.

[4] McClure, M. T., *An Introduction to the Logic of Reflection,* New York, Holt, 1925, p. 469; see also pp. 448–471.

Mechanical explanation is valuable so far as it goes, but it is incomplete. From the philosophical standpoint it is an integral phase of teleological explanation. Since the purpose of mechanical explanation is to know the truth about the world, the scientist himself cannot be explained apart from teleology.

To organize our partial knowledges more fully means more adequately to grasp their inner relations and their values. In these higher systems of knowledge, notably in philosophy, purposive explanation attains its most perfect expression. Here alone can scientific laws themselves find an explanation. Here truth attains its deepest and richest significance. It is in such a whole that the universe itself must be explained, for we cannot refer it to any cause or genus outside of itself. Philosophical explanation is an endeavor to find within reality itself the ultimate principles which will enable us to understand its true nature. We explain the universe by organizing the facts and values we discover and create in it.

(*f*) *Parsimony and Fallacy in Explanation.* — A major requirement of good explanation is that it be as simple as possible. An explanation is simple when it involves a small number of terms or ultimate principles. Complexity of explanation is often a token of immaturity or uncertainty. F. H. Bradley has coined the maxim, "If I saw further I should be simpler." The subtle religion is likely to be the superficial one; and elaborately ornamental art is decadent art. A theory can be discarded without loss if it does not actually help to account for the facts to which it claims to refer.

This desideratum of simplicity is known as the *postulate of parsimony.* Because it is a sharp instrument for cutting out useless hypotheses, it has long been called Occam's razor. It is named after a medieval philosopher, William of Occam (1280–1347), who laid down the maxim that in metaphysics "one should not multiply principles unnecessarily." The scientist feels a presumption in favor of the simpler theory. In geometry the best demonstration is commonly regarded as the one involving fewest premises and fewest steps. The theories of gravitation, of atoms, of cells, and similar theories, have strengthened the scientist's belief that natural phenomena admit of economical explanation. The physicist, K. K. Darrow, recently declared, "Perhaps there would be no better way to describe research in pure science than this, to say that it is inspired by the desire of finding phenomena either possessed of ultimate simplicity, or else capable to some extent of being imitated by a simple model." [5] The scientist, however, must nowhere allow his preconceived wish to warp the relevant facts as they exist.

A number of subtle fallacies are likely to infect our explanations of things. We shall consider only two of them. 1. The combination of intellectual laziness with our love of order often leads us to be satisfied with a

[5] *Introduction to Contemporary Physics,* New York, Van Nostrand, 1926, p. xvii.

false simplicity or a one-sided view of a problem. Then we fall into the *fallacy of neglected whole,* which is illustrated by the ethical hypothesis that the supreme end of life is pleasure. Thinking which is needlessly fragmentary or partial keeps us from undistorted truth more often perhaps than anything else. The maxim, *Consider the context,* cannot too often be recalled.

2. Biology has led us to look for the explanation of things in "the aboriginal and the germinal." It is commonly supposed that if, by thorough analysis, we can trace anything back to its origin or reduce it to its elements, we shall find its complete explanation. Since value always lies in the functioning of a whole, this search for meanings in beginnings is destined to be fruitless. The confusion of origin with value has been called the *genetic fallacy.*[6] "The way a thing has originated," declares McClure, "has little or nothing to do with the value which accrues to it after it has come into being."[7]

For example, many sincerely religious people have opposed the biological theory of evolution on the mistaken assumption that man's worth is destroyed by his having had simian ancestors. On the contrary, the significance of man's life seems to lie in the present capacities and dignity which he possesses. The beginnings of man, taken by themselves, are no more self-illuminating than a seed considered apart from the plant and the fruit which grow from it. The consummations of man's life, as viewed in the light of his whole evolution, explain him far more profoundly than does his genesis. The ancient question, "Is not this the carpenter's son?" forever warns us against the genetic fallacy.

7. The Classification of the Sciences

Scores of philosophers and librarians have striven to draw an orderly map of the vast regions of human knowledge.[8] An ideal system of the sciences would have a fitting logical place for every branch of knowledge. This ideal calls for a single principle of arrangement which shall be both illuminating and applicable, and which shall not result in too much overlapping of species. Such a principle, however, is exceedingly difficult to find because of the diversity among the sciences. Some classifications are so summary that they omit important distinctions which exist; others are so detailed that they conceal any unity which may be present. Without

6 *Cf.* Hibben, J. G., *A Defence of Prejudice, and Other Essays,* New York, Scribner, 1921, pp. 73–77.

7 McClure, *op. cit.,* p. 453.

8 *Cf.* Flint, Robert, *Philosophy as Scientia Scientiarum and a History of the Classification of the Sciences,* Edinburgh, Blackwood, 1924.

attempting an original classification of the sciences, we shall present four of the most successful historical ones.

(*a*) The Classification of Comte. — The great French philosopher, Auguste Comte (1798–1851), in his *Cours de philosophie positive,* develops a simple and profound scheme which has inspired many other classifications. Because speculation and action are two basic phases of human life, he first distinguishes between theoretical and practical sciences. He leaves to the specialist the determination of the special sciences, and seeks the right order among the theoretical general ones. Those should come first, he said, which have the most general field of study and the widest application. Also, these first sciences must treat of the simplest phenomena. Increasing complexity, then, furnishes one principle of arrangement. Clearly, inorganic or physical phenomena are simpler than organic phenomena, and individual life is simpler than social life. Further, since mathematics is the indispensable tool of all other sciences, yet independent of them, it stands first in the list. His plan of the year 1830 is as follows:

Table X. Comte's Classification of the Sciences

				(1) Mathematics
I. Theoretical Sciences	A. General Sciences	1. Inorganic phenomena	a. Celestial.....	(2) Astronomy
			b. Terrestrial	(3) Physics
				(4) Chemistry
		2. Organic phenomena	a. Individuals..	(5) Biology
			b. Species......	(6) Sociology
	B. Special Sciences (*e.g.* botany)			

II. Practical Sciences (corresponding to theoretical ones).

In sociology he at first included morals, economics, the philosophy of history, and a large part of psychology. Later he made ethics the seventh culminating science. There are adequate reasons now for inserting psychology between biology and sociology. We should also put logic before mathematics and place metaphysics beside or above the whole series.

The greatness of Comte's classification lies in his striking success in realizing without conflict several important principles. The sciences are so arranged that each one, except the first, depends more or less upon the results of its predecessors, without itself exercising any influence upon them. Comte believed that in each of the six fields a new property or kind of phenomenon appears which cannot be explained in terms of the principles of the earlier sciences. Further, while the first in the series are remotely connected with humanity, as we advance to ethics they become more and more vitally related to human welfare, to which he was ardently devoted. In

short, if one moves up the series, the sciences increase in generality, in simplicity, and in independence. *A science which is relatively simple, abstract, and independent always precedes one which is more special, complex, and dependent.* His arrangement had the additional merit of bringing together the sciences which have the most overlapping of problems. With the amendments suggested, it is still a valuable classification. The plan of the first part of this book conforms closely to it.

(*b*) THE CLASSIFICATION OF THOMSON. — Chapter IV of J. A. Thomson's *Introduction to Science* contains a valuable criticism of various historical attempts to classify the sciences. This chapter ends with the adoption of the scheme reproduced in Table XI. Thomson (English biologist, born 1861) divides the sciences into two basic groups: (1) abstract, formal, or methodological sciences, and (2) concrete, descriptive, or empirical sciences. The abstract sciences, he says, "deal with methods of inference, supply intellectual instruments for investigation, and test the consistency and completeness of scientific descriptions." The concrete sciences "deal with the facts of experience and with inferences from these facts." The concrete sciences are arranged in four divisions as indicated in the table. The first of these four divisions is made up of the five general or fundamental sciences. In the remaining divisions only the most important examples can be included in the space available.

A notable contribution of Thomson's classification consists in the recognition of a group of composite or synthetic sciences, such as anthropology and geography. It is somewhat unfortunate that Thomson places chemistry before physics, since physics is generally regarded as the fundamental natural science. The result is that chemistry is separated from biology, to which it is intimately related, and the dependence of medicine upon chemistry cannot be indicated. The positions of several other sciences suggest limitations which actually they do not possess. Especially is it true that ethics is unwarrantably restricted when it is conceived solely as a phase of applied psychology.

(*c*) THE CLASSIFICATION OF DEWEY. — Melvil Dewey (American, born 1851) has originated a decimal system for classifying books, pamphlets, and every other kind of printed or written material, which is also a classification of the sciences. It was developed in 1873 and first published in 1876.[9] It is based upon ten supreme fields or classes of knowledge, of which the first or zero (*i.e.*, not limited) class contains general works. Each of these ten classes contains nine divisions in addition to a zero division for the general materials of the class. Each of these ten divisions is similarly divided into ten sections. The subdividing process may be carried as far as

[9] Ed. 12 of Melvil Dewey's *Decimal Classification and Relativ Index* appeared in 1927; Dorkas Fellows, editor.

TABLE XI. J. A. THOMSON'S CLASSIFICATION OF THE SCIENCES*

ABSTRACT SCIENCES	CONCRETE SCIENCES: GENERAL	SPECIAL OR DERIVATIVE	COMBINED OR SYNTHETIC	APPLIED
METAPHYSICS (Supreme)	V. SOCIOLOGY	Ethnology Study of Institutions	Science of Human History	Politics Civics Economics
LOGIC	IV. PSYCHOLOGY	Esthetics Linguistics Psycho-Physics	Anthropology	Ethics Education
STATISTICS	GENE-OLOGY | MORPH-OLOGY | PHYSI-OLOGY | AETI-OLOGY III. BIOLOGY	Zoology Botany Protistology	General History of the Biosphere	Eugenics Medicine Forestry
MATHEMATICS (Fundamental)	II. PHYSICS	Astronomy Geodesy Meteorology	General History of the Earth Geology Geography Oceanography	Navigation Engineering Architecture
	I. CHEMISTRY	Spectroscopy Stereo-Chemistry Mineralogy	General History of the Solar System	Agriculture Metallurgy Mining

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the subject-matter requires. Each step is clearly marked by an additional decimal place. An alphabetical index of forty thousand heads makes ready reference extremely easy. The method of numbering the first hundred divisions is indicated in Table XII. This table may be useful to students who work in libraries in which the system is employed.

The importance of this system lies primarily in the fact that it has proved to be extensively and practically useful in the organization and administration of libraries. The scheme of classification has been translated into a dozen languages and is employed on every continent. It has grown steadily in use until it is now employed in more libraries of the world (probably about nine tenths) than all other systems combined. It has been estimated that fourteen thousand of the world's public and private libraries employ it.[10]

The author of this system has sought, and attained, practical utility and economy more than theoretical harmony and exactness. It is regrettable that such a widely used system, in spite of its practical success, contains some logical defects. For example, philology is separated from both literature and history, with either of which it might naturally have been placed. While the order of the natural sciences is logically excellent, the divisions of philosophy are disorderly, and the sections under religion are out of proportion; one number must take care of all non-Christian religions.

(*d*) THE CLASSIFICATION OF MÜNSTERBERG. — Another notable classification of the sciences is the working plan of the International Congress of Arts and Science which was held in September, 1904, as a part of the Universal Exposition at St. Louis. While many minds contributed to this remarkable scheme, the dominating genius in its construction was Hugo Münsterberg (1863–1916), a distinguished psychologist and philosopher of Harvard University.[11] Since man lives in a physical and social world, Münsterberg started, inevitably, by recognizing the social and *physical sciences* which Comte had emphasized. Since psychology had won an independent place for itself by the end of the nineteenth century, he put this with sociology to make the main division of the *mental sciences*. Much of youthful psychology had been dominated by mechanistic descriptions, due to the influence of the successful physical sciences. This incomplete causal psychology, he said, must be supplemented by a purposive psychology, by a spiritual apprehension of the ends or values which men strive to realize. By classifying human purposes in two ways, he derived two other parts of his system in the following manner:

10 *American Library Association Bulletin*, September, 1926, p. 167.

11 Münsterberg recounts the evolution of this scheme in the *Atlantic Monthly*, 1903, Vol. 91, pp. 671–684.

Table XII. Divisions of the Dewey Decimal Classification *

000 GENERAL WORKS; PROLEGOMENA
- 010 Bibliografy
- 020 Library economy
- 030 General cyclopedias
- 040 General collected essays
- 050 General periodicals
- 060 General societies; Museums
- 070 Journalism; Newspapers
- 080 Polygrafy; Special libraries
- 090 Book rarities

100 FILOSOFY
- 110 Metaphysics
- 120 Special metaphysical topics
- 130 Mind and body
- 140 Filosofic systems
- 150 Psychology
- 160 Logic; Dialectics
- 170 Ethics
- 180 Ancient filosofers
- 190 Modern filosofers

200 RELIGION
- 210 Natural theology
- 220 Bible
- 230 Doctrinal; Dogmatics; Theology
- 240 Devotional; Practical
- 250 Homiletic; Pastoral; Parochial
- 260 Church; Institutions; Work
- 270 General history of the church
- 280 Christian churches and sects
- 290 Nonchristian religions

300 SOCIAL SCIENCES; SOCIOLOGY
- 310 Statistics
- 320 Political science
- 330 Economics; Political economy
- 340 Law
- 350 Administration
- 360 Associations and institutions
- 370 Education
- 380 Commerce; Communication
- 390 Customs; Costumes; Folklore

400 FILOLOGY
- 410 Comparativ
- 420 English
- 430 German
- 440 French
- 450 Italian
- 460 Spanish
- 470 Latin
- 480 Greek
- 490 Other languages

500 PURE SCIENCE
- 510 Mathematics
- 520 Astronomy
- 530 Physics
- 540 Chemistry
- 550 Geology
- 560 Paleontology
- 570 Biology; Ethnology
- 580 Botany
- 590 Zoology

600 USEFUL ARTS
- 610 Medicin
- 620 Engineering
- 630 Agriculture
- 640 Domestic economy
- 650 Communication; Business
- 660 Chemic technology
- 670 Manufactures
- 680 Mechanic trades
- 690 Bilding

700 FINE ARTS
- 710 Landscape gardening
- 720 Architecture
- 730 Sculpture
- 740 Drawing; Decoration; Design
- 750 Painting
- 760 Engraving
- 770 Fotografy
- 780 Music
- 790 Amusements

800 LITERATURE
- 810 American
- 820 English
- 830 German
- 840 French
- 850 Italian
- 860 Spanish
- 870 Latin
- 880 Greek
- 890 Other languages

900 HISTORY
- 910 Geografy and travels
- 920 Biografy
- 930 Ancient history
- 940 Modern: Europe
- 950 Modern: Asia
- 960 Modern: Africa
- 970 Modern: North America
- 980 Modern: South America
- 990 Modern: Oceania and polar regions

* Reprinted from *Decimal Classification,* by permission of the publisher, Lake Placid Club Education Foundation, Lake Placid Club, New York.

First, he distinguished between individual and more-than-individual purposes. The ramifications of the former in political, legal, literary, and religious life constitute the subject-matter of the *historical sciences.* Then there are purposes or norms, such as beauty and truth, which have significance for every human subject. The several disciplines, logic, esthetics, etc., which study these purposes, make up the *normative sciences.* Metaphysics belongs here because it deals with the ultimate ends of life, with the meaning of reality as a whole. Mathematics, also, is an ideal or normative science since it is not a study of the things of sense, but of " objects made by the will, created in the service of logical purposes."

Secondly, human ends may be classified according to whether they are theoretical or other-than-theoretical, *i.e.,* practical. The theoretical purpose of knowing finds expression in the four great scientific groups already determined: normative, historical, physical, and mental. The practical sciences, or arts, might be grouped either with reference to the theoretical sciences they seek to apply or to the ends sought. Because most applied sciences make use of several theoretical sciences, it is simpler to divide them by reference to the ends they realize. Accordingly, the main divisions of the practical sciences are called the *utilitarian,* the *regulative,* and the *cultural* sciences.

The resulting seven divisions of the whole are divided further into 25 departments, as indicated in Table XIII. These admit of extended subdivisions; in the arrangement of the sessions at St. Louis it was convenient to have 130 sections, 71 theoretical and 59 practical.[12] This illuminating organization of knowledge will probably afford for a long time a logical place for the new sciences which are frequently being born.

8. The Scientific Attitude

Since every stage of science is methodical, a synoptic account of the scientific spirit will form a fitting conclusion to our discussion of system as well as to our whole discussion of scientific method in Part Two. *By a science is meant an organized body of tested knowledge based upon the accurate observation of relevant phenomena.* While much everyday knowledge is conjectural, indefinite, and conglomerate, knowledge that is called scientific is articulate, well verified, and systematic. It is stated in as exact and simple a way as possible, and describes in general terms (theories and laws) the relations among facts which have been proved to exist. It is usually the product of many minds that have labored in the spirit about to

[12] *Cf. International Congress of Arts and Science,* Boston, Houghton, Mifflin, 1905, Vol. I, pp. 15, 47–49, 85–134.

TABLE XIII. MÜNSTERBERG'S CLASSIFICATION OF THE SCIENCES

I. THEORETICAL SCIENCES (studies of facts for the sake of knowledge):

- Division A. NORMATIVE SCIENCES:
  - Dept. 1. PHILOSOPHY:
    - Sec. A. Metaphysics
    - B. Philosophy of Religion
    - C. Logic
    - D. Methodology of Science
    - E. Ethics
    - F. Esthetics
  - Dept. 2. MATHEMATICS:
    - Sec. A. Algebra and Analysis
    - B. Geometry
    - C. Applied Mathematics
- B. HISTORICAL SCIENCES:
  - 3. Political and Economic History
  - 4. History of Law
  - 5. History of Language
  - 6. History of Literature
  - 7. History of Art
  - 8. History of Religion
- C. PHYSICAL SCIENCES:
  - 9. Physics
  - 10. Chemistry
  - 11. Astronomy
  - 12. Sciences of the Earth
  - 13. Biology
  - 14. Anthropology
- D. MENTAL SCIENCES:
  - 15. Psychology
  - 16. Sociology

II. PRACTICAL SCIENCES (studies of facts in relation to ends):

- E. UTILITARIAN SCIENCES (serving material welfare):
  - 17. Medicine
  - 18. Technology
  - 19. Economics
- F. REGULATIVE SCIENCES (harmonizing human interests):
  - 20. Politics
  - 21. Jurisprudence
  - 22. Practical Social Science
- G. CULTURAL SCIENCES (aiming at the ideal perfection of man):
  - 23. Education or Pedagogy
  - 24. Practical Esthetics or Art
  - 25. Practical Religion

be described, and is, therefore, largely to be gained through the critical appropriation of the work of others.

Of the many points of view from which the scientific attitude may be studied, we shall review it from only two; first of all, with reference to its *logical marks.* The operations of the scientific mind are a blend of careful observation, creative imagination, logical inference, and critical verification. The genuine scientist has an open, progressive mind, and endeavors to

free his conclusions from hasty and untested generalizations, errors, and prejudices. He desires both to know the relevant results of other thinkers and to push observation and testing further. With his comprehensive outlook upon his own and adjacent fields he combines an eagerness to analyze thoroughly the smallest details that seem of significance. Also, he carries forward his investigation with a certain form, finesse, or plan: he is at once methodical and critical in his procedure, and precise and orderly in the formulation of his results. He has a keen " sense of the interrelatedness of things "; an isolated and unexplained phenomenon in his field disturbs him until he understands it. Above all, he feels the need of evidence and proof, and adopts what Karl Pearson calls " the final touchstone of equal validity for all normally constituted minds." *The sexad of logical virtues is: significance or relevance, clearness, truthfulness, orderliness, comprehensiveness, and progressiveness.*

We obtain another picture of the scientific attitude when we view it from the standpoint of the scientist's *mental activity.* The trained scientist commonly manifests in a variety of ways a striking forcefulness and vigor. He has a " passion for facts," an eager desire to know the truth. He loves better to search for knowledge against discouraging obstacles than to remain in dark and unquestioning ignorance. In consequence of his insatiable will to truth, he throws aside encumbering prepossessions, and wins for himself an impartial attitude toward his problems. He attacks his problems with vigor, and propounds a multitude of fresh and helpful questions concerning them. He observes alertly, sustains criticism, and suspends judgment when necessary. He exerts his imagination in attaining novel standpoints, in discerning new relationships, and in creating fruitful hypotheses. He has patience and perseverance in collecting data and in verifying his hypotheses, and both caution and courage in announcing his conclusions. He has, in short, what Bacon called " a nimble and versatile mind," and lives an exceedingly energetic and aggressive intellectual life. Bacon also declares, " If a man can play the true logician, and have judgment as well as invention, he may do great matters." Such a man harvests all the satisfaction that grows out of the unselfish pursuit of truth and all the happiness that comes with an ever-widening range of ideas.

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PART III

OTHER PHILOSOPHICAL DISCIPLINES

CHAPTER XVII

ETHICS

In the third and concluding part of this work it is our purpose to survey briefly certain fields of knowledge which, together with logic, or the study of scientific method, lie within that part of our cultural heritage called philosophy. The first of these to be studied is ethics.

Ethics is the reflective study of morality. It is a description and criticism of the aggregate of acts and attitudes generally approved and disapproved within human society. These few words indicate the field of interest with which we are concerned. Ethics, however, is far from being a subject to be discussed briefly, however succinct we may endeavor to be. There is profound disagreement among experts within the field, and a large number of standpoints to be considered. Only a few items in the fascinating story of human rights and goods can be chronicled here. A large part of the problems of the science of ethics necessarily lies beyond the scope of a brief chapter. We shall consider first the methods of the science. Then, employing various methods, we shall mention several notions which have been used in the discussion of the goods and bads, rights and wrongs, of human life.

1. The Methods of Ethics

J. A. Thomson, in his *Introduction to Science*,[1] classifies ethics, along with education, as an applied psychological science. All ethicists would agree to the importance of psychology in any study of human conduct, even though they might not so classify their science. The importance of psychology becomes evident when we see that those theorists who have held, historically, that psychology and ethics were not related, have done so in terms of a previous psychological theory. There was a theory from Plato, which came down through Kant into the modern period, to the effect that that sense (desire) and reason (will) are essentially separate. This separateness of the two faculties was stated as a contrast between an empirical world or realm, presented to sense, and a transcendental realm, open only to reason. For Kant, for example, ethics is in the latter sphere; and Kant thereby illustrates the influence of *psychological* notions, albeit antique

[1] Thomson, J. A., *Introduction to Science*, New York, Holt (Home University Library), p. 106.

ones, upon ethical theory. This may sound like a begging of the question, but it is important to state the historical fact that ethical theory has been very greatly dependent upon psychological standpoints. This fact of dependence helps to explain the contemporary differences among ethical theorists. With psychology in its present confused state, with behaviorists, existentialists, dynamic psychologists, Freudians, and *Gestalt* psychologists contending for his attention, what is the poor student of human morals to do! At all events, we should admit the importance of psychological method to ethical knowledge. Then we can criticize our psychological assumptions.

The fact is that most contemporary thinkers in the field of ethics have received their psychological training through the medium of a terminology which is not sound from the point of view of those who are more expert. Before the psychological method can be well employed, one must, of course, be up-to-date in one's psychology. This is another way of saying, with reference to our present purposes, that the psychological problem is antecedent to ethics. To the behaviorist, psychology, as the science of what men *do,* is fundamental to ethics, the science of what they *ought to do.* But, among others, there is also the existential point of view, which is concerned with an introspective [2] study of "consciousness," and holds that it can be studied apart from overt action. The view that one can close one's eyes and ears, and introspectively see oneself, relates to the theory that morality is purely subjective, that what men *are* is the significant thing, and that what they *do* is external, physical, and beyond the pale of consideration. Upon the whole, professional moralists have idealized the realm of inner consciousness into a "spirit" and made little of real activity or overt behavior. The making light of consequences, as morally unimportant, is one popular result of this type of psychological method in ethics. Motives become exclusively emphasized, and consequences are neglected. But, whatever may be the brand of psychology or its implications, the fact to remember is that there always are psychological assumptions in ethics.

A psychological analysis, however, independent of a social or sociological analysis, can throw light only upon the form of man's action — the *how* a man acts. *What* the man does, the subject-matter or content, has to be supplied from the social side. Social psychology and social science are here indispensable. They enable us to use in ethics the *sociological method.* Psychology can tell us that men get angry; it can observe and report various manifestations of anger. But psychology alone can never tell what men get angry at, or what they *do* when they are angry; beyond, that is, certain formal physiological phases of the result. Men do get angry at an "insult," but this is a social fact, not merely a psychological one. *What* is done

[2] See Chapter on *Psychology.*

— whether to challenge to a duel, to knock the man down, or something else — is determined by the social setting. Just as no amount of psychology would enable one to evolve a language, so no amount of psychological jugglery would enable one to evolve a code of ethics apart from a social setting. Society is the medium in which the psychological reactions take place. Psychology may give us, in ethics, a formal treatment of our duty — it can throw light upon the feeling of obligation and how it arises, but it can never tell us *what* causes it to arise socially, or *what* that duty is. The social background is as important as the psychological analysis in the development of a sane ethical viewpoint. Man is ineradicably social. His sociality requires neither explanation nor justification. He grows in groups. His very organs and original activities imply the presence of others of his kind. Any theory of morals which denies, either explicitly or implicitly, the social character of human nature distorts the facts.

The next method, the *anthropological method,* incidentally supports the contention just made as regards man's social character. Anthropology studies primitive human groups and attempts to reconstruct the history of early man. It leans very heavily upon biology, of course, as well as upon other neighboring fields, and it aids the study of morals by providing abundant genetic material. The *mores* of primitive groups — their standards of conduct, their punishments and rewards, their institutions — all throw light upon contemporary ethical problems.

A fourth, and related, method is the *historical method.* Its function is very similar to the one just mentioned, excepting that the material it provides comes from the records of human history. The historical development of standards and customs is as important as their primitive forms. History and anthropology afford a view of both to the student of ethics. History, thought of as a systematic and critical record of past events, is a dimension which must be taken into account by all sciences.

The fact that various methods, psychological, sociological, anthropological, and historical, can be indicated as important in ethical study must not be taken as meaning that any one of them can be operated exclusively with success. All of them involve induction, deduction, and verification, insofar as they are scientific at all. From this point of view there is only one method: scientific method, the method of thought. We must remember that a method is a " way to " a thing. When any group of things has more than one way to it, various methods may be distinguished. The subsequent discussions in this chapter will illustrate the intricate overlapping of the various methods we have mentioned. Human conduct is a continuum of integrating and disintegrating activities, a flow of dynamic energies. In seeking to understand it, we must use all possible scientific and philosophical avenues of approach to human life.

2. The Ethical Status of Original Activities

We have defined morality as the aggregate of acts and attitudes which are approved and disapproved, and have indicated thereby that human activities are the subject-matter of our science. In a previous chapter on psychology, the notion of human nature as a set of impulses was developed. Actual human conduct has its dynamic source in the specific potentialities of our original natures. It is interesting to note how approval and disapproval has been given, historically, to these original impulses themselves. We mention only three of the attitudes which have been taken.

Original activities, in the first place, have been condemned as *bad.* Stoicism, in ancient times, was very suspicious of our original natures. Human impulses must be held in check, repressed. The truly good man, the Stoic "wise man," was the one who reached a condition of apathy in which he rose superior to the sufferings of his passionate nature. The whole drift toward ascetism which came into the ancient world from the east involved a condemnation of man's original nature. Monasticism was a denial of the natural impulses which lead to family life. Fastings and celibacy were taught as virtues on the ground that the mortification of the "flesh" was essential to morality. The theological doctrine of "original sin" is an intellectual occasion, or justification, for such repressions. Man's nature is corrupt and sinful. His conduct is tainted at the source, and, naturally, he is headed for eternal punishment. Apart from a supernatural mechanism of salvation, he can have no hope. The condemnation of man's nature was pushed to the absurd point of maintaining that there are "babies in hell no longer than a span" — there because of the evilness of their natures. The psychological ground of such ideas is obvious. Original impulses are difficult to control. The more difficult they have been to control the more they have been emphasized as evil. Impulses which have caused so much trouble and suffering must be bad! The cure is to eradicate, or metamorphose, the impulse. So the argument ran and, in the absence of any other technique, asceticism and supernaturalism resulted.

A second attitude toward original activities, the other extreme, is to call them *good.* The Romanticists are excellent illustrations of this tendency. Nature is good; man is a part of nature. Therefore, his impulses are essentially good and need liberation. Freedom is all that is necessary to morality. Liberate the beneficent springs of human action and let men live! Rousseau (1712–1778) was the modern prophet of such doctrines of original nature. Man is naturally free and noble, he said, and it is his civilization which has put him into chains. In religion the tendency is expressed in Antinomianism. One Russian sect, believing in the goodness

of orginal nature, having immigrated to Canada, started on a pilgrimage without the usual formality of wearing clothes. This might have been logical enough from the point of view of the communicants, but the Canadian police saw it in another light! This type of doctrine concerning original impulses is associated with revolts against conventions. In times of revolution the springs of human action, thought of as the powers which liberate man from tyranny and oppression, are easily regarded as good in themselves. The motivation of this approval of original activities is as clear as is that of the previous contradictory position. Where the unusual is not wanted, its source is called bad; where it is desired, its source is called good.

A third position regards the native tendencies of man as ethically *neutral.* They are neither good nor bad in themselves; they are indifferent. The classical exponent of this doctrine was Aristotle. Original nature is merely the raw material of morality. It may issue in virtue or in vice, but in itself it is neither. We are not virtuous or vicious by nature, but we have naturally a capacity for both, and by habituation we become one or the other.[3]

Other distinctions concerning human nature have been made historically in the various discussions of morality, but these three illustrate sufficiently the problem involved. Shall we say that our original activities are *good, bad,* or *indifferent?* If we say, for instance, that they are indifferent, what does this mean? It does not mean that original nature has nothing to do with moral character. That would be absurd. Moral character is a combination of predispositions to act in certain ways in certain situations, and these predispositions are *native activities as they have been conditioned by exercise.* The position of Aristotle is essentially sound at this point. Virtue must be acquired by each generation. Moral excellence rests upon native abilities, but the fruition of these capacities into character is the result of habituation.

3. The Nature of Good

The nature of *good* has been a stock problem in ethics for about twenty-five hundred years. Since the days of ancient Greece philosophers have puzzled out theories of the good, the really good, the *summum bonum,* and various related notions. These theories have been on various levels of generality. Some discussions have been fruitful; others have been useless. The notion of "good-in-itself" has been, for the most part, in this latter class. Abstraction proceeds from adverb to adjective, to noun, to thing-in-itself. Things are done *well,* they are *good.* Then they become *goods,* and

[3] Aristotle, *Ethics,* Bk. II.

finally *the good* comes to be thought of. When *the good* is defined apart from all concrete human interests, abstraction is complete; the discussion has become hopelessly academic. In fact, goods do not exist apart from human interest, unless perchance we wish to say that the banks are good for the river, or coral is good for the coral island. But this is not the kind of good ethicists have discussed; it is rather some certain kind of value which has been hit upon in theory and then universalized as *the* good. The hedonists' definition of pleasure as the good is a classic example of this, or Aristotle's notion of happiness, or his idea of god-like reflection, *purus actus.* Such notions of *the* good have very little utility. The reason for this is that what is good in one situation may not be good in another.

The moral life is not a sphere in which " utter abstruse abstraction " can be of much help. Its subject-matter has relatively little uniformity and eludes the quantitative techniques which are so useful in physical science. There is no mathematics of morality. One cannot select the goods of life by algebra or differential calculus. There is too great qualitative richness. Aristotle expressed this when he said that to expect complete demonstration in these spheres (he was referring to ethics and politics) was the sign of a want of education. But, admitting this, generalizations of some sort must be made, else there is no science of ethics. That we do have moral knowledge seems clear, in spite of the fact that what we take for moral knowledge often turns out to be something else. If we begin by searching for goods rather than *the* good, by paying attention to *valuables* rather than trying to find *value in general,* we shall be upon the right track.

Anything, the alienation of which we spontaneously resist, is good. One class of goods is distinguishable, therefore, as *natural goods,* non-reflective in the sense that we become aware of them only when we are about to lose them. To put it differently, they are the goods which we have without knowing it, or hit upon without anticipation. Air is good to us; we spontaneously resist suffocation. Or, we may be walking along a hot, unfamiliar road and stumble upon a cool spring. Unreflective goods are goods about which we do not deliberate. They, of course, are *classed* as goods only *ex post facto,* when we reflect about them.

Contrasted to unreflective goods are reflective goods or valuables, the things about which we make judgments of value, the worth of which we estimate. These appear as the means or the ends in reflection. Among these we choose, in each situation, the *better.* It is this matter of choosing the better among goods which brings the moral life to a focus. When we are confronted with novelty, perhaps with a situation which overlaps very slightly upon our previous experience, how does the moral choice take place? How is the good of *this situation* determined?

Here appears the *rôle* of intelligence in morality. We are assuming, of course, that genuine alternatives are present. Deliberation, as we have indicated above,[4] is a process of dramatic rehearsal of the consequences of alternative courses of action. We " try on " courses of action as we might try on hats, to see which one suits us the best. The illustration is not pat, in that the courses of action are made by our trying them on. They are not ready-made, as are hats. The actions we refuse to do never become existent; they have only the imaginative reality which our anticipation gives them. Hats exist, and are afterwards worn; courses of action exist only in the doing. In deliberation, we imaginatively con over the alternatives in prospect, and the alternative which integrates our impulses and releases our activity is selected. This course of action is selected as " good." *The end-in-view, set up in deliberation as the projected terminus of the contemplated action, is the good of the particular situation.* Hit upon in imagination, it trips our activities and calls us on to reach it.

This is the type of experience referred to by some ethicists as *intrinsic* good, with this exception — that we are thinking of it as appearing *within* the process of deliberation. The end-in-view does not exist independent of thought. Usually, as a matter of fact, the actual terminus of our action is either better or worse than we foresaw. Goods are not independent of human life and purposes. Objects do not possess goodness as they do color or weight. They are good or bad as they *function* in our experience. The concrete situation is the test. Money, " the root of all evil," is also the indispensable means of a liberal life! The *situation* is absolute; and it is absolutely variable. Therein lies the difficulty of the moral life. Continued reflection is essential.

We have distinguished (*A*) *natural goods,* the items which are hit upon accidentally or reflected upon, in retrospect, when they are past, and (*B*) *reflective goods,* which involve (1) *ends-in-view,* goals or aims which are set up to be achieved, purposes which lure us on to fulfilment. A correlative sense of the word good may be used to indicate (2) *instrumental goods* — the means which we select, in reflection, to reach the ends for which we strive. A thing is good which furthers some process already engaged in. To mention these is to define them; they are the items which are good *for* other things. In the specific situation they are the steps which are indispensable to achieving the end-in-view. For example, leisure, industry, and financial resources, among other items, are necessary means for achieving an academic education.

[4] Chapter on *Psychology*. The author quoted Professor Dewey's theory of deliberation, and cannot refrain from mentioning again his intellectual debt to Professor Dewey.

4. Means and Ends

The distinction between means and ends is a fundamental technique of reflection. Thought could not go on without it. How important it is in the mechanism of deliberation becomes apparent upon a very cursory analysis. A constant adjustment of means and ends takes place as alternative courses of action are contemplated in imagination and successively rehearsed for selection. Indeed, we can define intelligence as the business of adjusting means to ends. Furthermore, within the specific situation the distinction of means and ends is absolute. They develop together, and their precise and separate formulation is the process we call deliberation. But in the same situation the end is never the means, and vice versa. The end in one situation may be means in the next, of course; that is to say that action goes on in time. But the end, the intelligent end, is always the end of *these* means, and the means are always the means to *this* end. The two appear together as the activity takes form. We mean by *end* the terminus of our projected action — that which *ends* it. It is the target of our contemplated action. The *means* are the near-by first steps in the projected activity. Whether we concern ourselves first with the near part (means) or begin with the far part (ends) is a matter of the technique of analysis in the situation. Whether, for example, we look at the target first and then at the sight of the gun, or vice versa, is a matter of technical detail. Of course, if we look only at the target and never at the gun, the former will never be hit; and, if we look only at the gun and never at the target, it may be an excellent gun, but it will be forever " good for " nothing!

Means and ends are strictly correlative; the distinction is an essentially practical technique within the process of deliberation itself. If, in thought, either becomes exclusively emphasized to the exclusion of the other, a distortion of the true function of thought takes place. If means are overemphasized, we get a practical materialism. Absorption in ends, with an accompanying neglect of means, gives us a false idealism. Genuine morality does not consist of amassing means without reference to the purposes they may serve, nor is it the contemplation of ends which have no possible means of realization. Ends, abstracted from our real experience and called " Ideals," are just as dangerous as a too great and near-sighted attention to instrumentalities. Means and ends go together. If we mistake the technique, we may become morally short-sighted, as was King Midas; or, getting lost in our contemplation of " Ideals," we may wander as did the ancient philosopher who, absorbed in the observation of the celestial bodies, fell into a well and broke his neck.

There is a popular adage which reads, " The end never justifies the

means," and which well illustrates the importance of correct thinking in these matters. Strictly speaking this adage is not true. If the end does not justify the means what does! The real meaning of the saying is to warn one of the importance of checking carefully the means used for realizing an end. No act has merely one consequence, and in thinking about a consequence of an act we may become fascinated by it. The more drive and motive there is behind the act the more oblivious of the other conse-

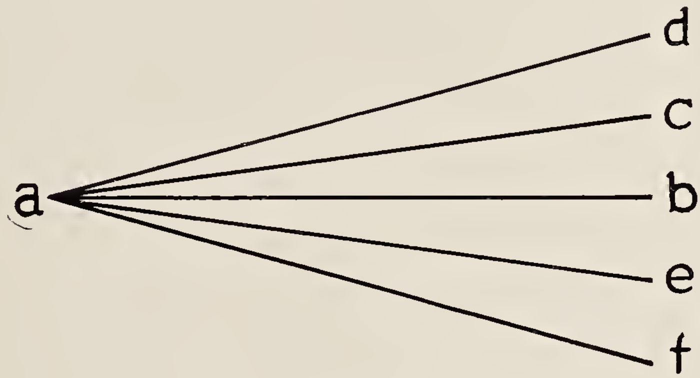

Fig. 25. Means and Ends

quences do we tend to become. The act *a* is a means to the end *b;* but also following from it are the consequences *c, d, e,* and *f*. If we forget the other consequences, the desirability of *b* may lead us to do the act *a,* even though *c, d, e,* and *f* are all consequences to be avoided. When the injurious character of the other consequences is so pronounced as obviously to overbalance the desirability of the end-in-view, then the performing of the act is to be avoided. That particular means is a poor one. The real meaning of the old adage, therefore, is this, Be sure that the means to your ends are not so bad as to entail consequences, perhaps unforeseen, which are overwhelmingly bad.

The pathos of the moral choices of life lies in the fact that we are unable to foresee all the consequences of the performance of an act. Stupidity is the very essence of immorality. We have, indeed, a moral obligation to foresee the consequences as far as we can. While no one can be held responsible for consequences which no amount of foresight could predict, the most damning thing that can be said about a person is that he merely " means well "!

5. The Nature of Right

Another distinction which is useful in the science of ethics is the contrast between *right* and *wrong*. *Right,* generally speaking, has to do with the *claim* which action has on us. Right action is action which others

approve in us, or which we approve in others. Right is not synonymous with good. It may be *right* for brave men to die horrible deaths on behalf of their country, but such deaths are never thought of as *good.* It always would have been much *better* if they had not died! The good in a war situation is the defeat of the enemy, and the risk of death is accepted as a necessary, albeit disquieting, means.

The content of the judgments of *right* and *wrong* is the approvals and disapprovals of the group. We have a *right* to do what others *tolerate* us in doing. When others cease to tolerate a specific kind of act, we cease to have the correlative right. The dominating group in any society obviously has much to do with what is tolerated, and what is not, within the group. The content of right and wrong tends to be set by the persons in actual power. Historically this fact is attested even by the language of morality. A " villain " was a serf in medieval days; now he is a bad moral character. A " noble " was a high feudal official; now it is a term of moral approbation — a " noble youth." Right and wrong have to do with the traditional morality of a group, and the content of right is determined by the actual development of any given society. Progressively the content of right is criticized in terms of the good, and the shifting of the content of what is tolerated, and what is not, takes place in terms of this criticism. For example, it has become *wrong* in the United States to distill alcohol for beverage purposes because, in the experience of numerous citizens, its use in such a manner has been judged *bad.* The relation is, of course, reciprocal. The young tend to judge good and bad in the framework of right and wrong as set by the community.

In general, we tend to judge right and wrong, as well as good and bad, spontaneously, immediately, dramatically. We approve or disapprove, adopt or reject, in terms of the predispositions of our nature as well as in terms of the possibilities of the situation. These predispositions, as we have said, constitute our moral character. But *good* and *bad* refer to that which the agent himself *accepts* or *rejects* in action; *right* and *wrong* to that which *others* accept or reject in the agent's action.

6. The Function of Moral Standards

Even so cursory an analysis as the present one is incomplete without some mention of the function of ethical standards. The place of these in the moral life is implied by what has gone before, and can be made explicit in very few words. The business of an ethical standard is to help us to solve our moral problems. Insofar as our problems overlap, generalized rules are possible. As has been indicated above, the qualitative disparity of our problems is the great difficulty confronted in employing a moral

rule of the popular type. " Thou shalt not kill " is a useful maxim, so long as one is on the street corner of a well-ordered society. One is not likely to employ it on the battle front, nor when confronting a desperado who threatens the life of women and children! *Absolute rules are out of place in ethics.* The very same kind of conduct which is reprehensible in one situation may be morally demanded in the next. What is needed in the moral life is the substitution of scientific method for popular maxims. *Morality is a matter of being as intelligent as possible in the concrete situation.* The *good* and the *right* must be discriminated afresh each time. Every advantage must be taken of accumulated wisdom and scientific analysis; and, when all is said and done by way of precaution, we make our choice and take the consequences.

7. The Nature of Conscience

Conscience has been given extensive treatment by some students of ethics, who have regarded it as a focal problem of morals. The derivation of the word is interesting. It meant, in old Latin, " knowledge," or " reflection." Elizabethan usage is similar. When Hamlet says, " Thus conscience does make cowards of us all," [5] he means, as the context well shows, that contemplation may cause us to be " sicklied o'er with the pale cast of *thought*." [6] The use of *conscience* as a term referring specifically to the moral consciousness is a later development. It has come to indicate, popularly, the moral stresses and strains within the individual agent which lie below the level of thought and which, in reflective deliberation, condition the dialogue form so characteristic of thought.

Conscience has been taken as absolute, as ethically authoritative. The " voice " of conscience has been thought of as divine, or as metaphysically irreducible. But the content of conscience turns out, upon analysis, to be a function of previous training, and the " voice " of conscience is the reflection in consciousness of the uneasiness attendant upon embarking upon new and untrodden paths. Ways of acting which are out of harmony with our habits may evoke a lurking remorse, even a sense of awe in extreme cases. On the other hand, actions which fall in with habitual activity may give one a complacent self-righteousness. How little the conscience, as it happens to function in any situation, is trustworthy as a guide to conduct becomes evident when this connection with previous training is realized. Its authority may be merely the authority of a socialized habitude. So defined, conscience is to be regarded more as a barometer of the profundity of the conflict involved than as a mentor to be consulted with reference to what should be done. Great confusion and emotional disturbance, and

[5] Shakespeare, *Hamlet*, Act. III, Sc. I.

[6] *Ibid.* Italics mine.

even a sense of mystery, may be involved when the habits involved are deep-seated, or infantile, and below the level of reflective memory. The emotional disturbance may be puzzling because the causes of it are too far back in the life of the individual to be recalled.

The term *conscience* may be used, of course, with reference to a rational principle which is being applied. In this sense it involves the notion of moral consistency, of acting in accordance with a consciously accepted rule. Here again its trustworthiness is not absolute, for in the really important moral crises of life the rules and principles to be applied are the very things in question. That one acts conscientiously in a particular case, therefore, means little beyond the fact that the act involved is "in character." Our conscience bothers us when we are "out of character."

8. The Self and Personality

Another favorite notion of ethical theorists is that of the *self*. The *self* has had an unfortunate career in the history of philosophy, for it has tended either to disappear altogether or to swell to include the whole of reality. In either case the utility of the notion is destroyed. It should be possible, however, to use the idea fruitfully without allowing it to drop out altogether, as in Hume's philosophy, or to spread over all other kinds of things. The *self* is, essentially, the organization of impulses and drives which becomes the core of the individual's character as it develops. Selfhood is acquired, in other words, as the social environment conditions the individual. The *self* is not an original datum, but arises as the individual is progressively held responsible by those around him. In holding the individual responsible, others are exercising control over him by using one impulse or drive against another. The using of impulses in this manner organizes a character by producing a hierarchy of traits and attitudes; the various activities frequently passed through are readily repeated, and character emerges as ordered habitual behavior develops. The *self is the pivot of reorganization,* as contrasted to the fringe of activities outside it. Illustrations are numerous. The child says, "*I* didn't do it!" when something has happened outside its deliberate control; the adult pleads, "I was not *myself*," to extenuate some improper act.

Personality is the representative social office of a self. When an individual has charge of important matters, the meaning of the whole of the activity is imputed to his person. His personality becomes enlarged, and he may become a "world figure," if the significance broadens sufficiently. Etymologically *persona* meant a "mask," such as an actor wore on the the stage, a meaning suggestive of the one just given. Kings and heroes are good illustrations. They take up into themselves the significance of the

whole which they represent. They stand for consequences significant to the whole social group. As president, some village lawyer becomes symbolic of the destinies of a state. As Pope, an obscure priest becomes the "vicar of Christ on earth." No differences in original nature can explain the differences in personalities among men. Personalities are manufactured — all too frequently merely by press agents and propaganda!

9. Conclusion

Many other topics of investigation come within the proper scope of the study of ethics. It is an intriguing field. Its practical significance is very great. Ethical science, properly understood, is a part of the general field of knowledge which is the equipment of every well-educated individual. It will not give him infallible rules, but it will help him to choose intelligently among life's possibilities. Many of the distortions which appear in various ethical theories spring from the desire to get a prior warrant, to eliminate all element of risk from moral conflict. Absolute standards are, in fact, impossible because the moral judgment is always a question. An antecedent guarantee of success is not possible. Nothing is to be gained by denying the fact of risk. The world is a contingent world, one in which genuine mistakes are made, and unatoned-for losses sustained. Whether it would be better otherwise, it is impossible to say. If we could be sure that every crisis is not a crisis, life would be tedious at least! Such a world would not be the one in which we live.

A healthy moral attitude, clear-eyed and robust, is represented in a fragment of Greek poetry, taken from a monument and quoted in the anthologies: [7]

> A shipwrecked sailor, buried on this coast,
> Bids you set sail!
> Full many a gallant bark, when we were lost,
> Weathered the gale.

P. W. W.

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[7] Quoted from unpublished lectures by Professor Graham Wallas.

CHAPTER XVIII

ESTHETICS

In the first and second parts of this book the austere, truth-seeking scientist is portrayed in his varied pursuits. He is the tireless analyst and experimenter, striving for a clear explanation of phenomena in terms of precise concepts and well-tested laws. These laws are objective, abstract, impersonal, from which the concrete personal worth of reality has been assiduously squeezed out. It is this significance which the lover and prophet, the philosopher and artist, each in his own way, is bent on apprehending. In the creation and enjoyment of the fine arts the emotions attain explicit and organized expression. The esthetic values embodied in them are esteemed among the chief treasures of life by those who happily have discovered them. To indicate their general meaning and some fruitful methods of studying them is the undertaking of the following survey of esthetics.

1. The Fine Arts, the Useful Arts, and Science

What are the fine arts? They are the creations, and the recreations, of sentient beings gifted with abundant spontaneity and imagination. Perhaps they originated as exuberances of man's practical and social behavior. Or they arose, perhaps, in man's precarious quest for dominion over his environment. When he encounters a nature that is hostile to or incongruous with his ideals, he strives to mould the outer world into accord with his inner wishes. *Any activity thus designed to transform natural material into objects that are useful or beautiful, or both, is art.* The product of this orderly intervention of the human hand and spirit is a *work of art.*

The germ of the fine arts emerges when the savage *adds* some ornament or decoration for its own sake to his language, spear, water-pot, or body. These fine arts grow freer and purer as they become more detached from the exactions of need and service. In the enjoyment of them appear and develop the intrinsic values of esthetic delight. Psychically, practical and esthetic attitudes are antithetical and exclusive; nor can one at the same time create and criticize, execute and contemplate. The utilitarian arts possess instrumental value; they minister primarily to man's material needs. They result from lavishing care upon objects possessed primarily for the useful ends they serve. Contrivances for use, of course, may also

possess beauty; indeed, perfect fitness to their proper ends may contribute to esthetic satisfaction, as in the case of a well-planned building. There is, however, an evident difference in motive between the plumber and poet, mechanic and musician, artisan and artist. The one puts first industry, discretion, efficiency; the other, sensibility, taste, harmony. The first includes various systems for doing things dexterously, such as carpentry, stone-cutting, and farming. These arts run over into the more methodical processes of the applied sciences, for example, navigation, agriculture, medicine, and engineering.

The useful arts stand in contrast with science as well as with the fine arts. Science and fine art thrive in contemplative activity as distinguished from practical endeavor, and each may be pursued for its own sake. Yet the sciences are akin to the useful arts in their ulterior goal of providing effective instruments for controlling nature. To insure this result they must be true in representing facts. The utilitarian arts are required to be efficient in achieving their specific ends. The fine arts (hereafter called art) are bound in neither of these weighty regards. They are the liberal arts, ends in themselves, created and enjoyed freely according to man's taste. They are expected only to give expression to interesting or beautiful situations which have become objectively vivid in the mind of the artist. If the fine arts happen to possess utility or validity, these qualities are secondary influences in esthetic satisfaction. In pure esthetic contemplation, every demand to act expediently or well, every urge to explain or predict, has been quieted. One yields to the wonder and the delight of the present vivifying moment, to the charm of the unique object engaging the senses and the imagination.

As science results in abstract symbolic formulas for making life intelligible, art exists in concrete forms, recording and generating emotional enjoyment. "We can listen to a striking clock as a succession of strokes which make a number or as a succession of tones which form a melody. Both attitudes are necessary to human life." [1] Art is monadic, realizing intensive values in insular unities; science seeks an understanding of the cosmic connections of phenomena in terms of extensive complications and universal principles. Thus, science and art happily yield complementary revelations of reality by emphasizing, without monopolizing, contrasting categories: reason and imagination, generality and individuality, mechanism and creativeness, causality and self-sufficiency.

Three aspects of science correspond with three phases of art: (1) the scientific investigator or researcher discovers (2) general laws and systems of knowledge which (3) the learner may appropriate for his own good.

[1] Delacroix, Henri, *Psychologie de l'art: essai sur l'activité artistique,* Paris, Alcan, 1927, p. 450.

In an analogous way (1) the artist creates (2) an harmonious object or work of art which (3) may bring enjoyment to an appreciative spectator. Of these three basic phases of art, we shall consider first the most tangible; namely, the work of art.

2. The Nature of a Work of Art

Some distinguishing marks of works of art — poems, temples, statues, paintings, symphonies — may now be suggested. *Artistic objects exist in definite individual forms presupposing human forethought, taste, and skill in fabrication.* While they are component parts of total reality, they have a significance called esthetic which other components do not possess. This distinctiveness arises from the fact that there are differing methods of satisfying desires: practical adjustments dictated by bodily needs, and the imaginative adjustments of the fine arts. In the first situation, we act as serious participants in the historical concatenation of events; in the other case, we are detached from the destiny of things, and leisurely survey them as free spectators in a realm of acknowledged illusion. The esthetic experience excludes such doings as seizing, consuming, dreading, or manipulating objects. In good pictures and dramas fruit does not suggest eating, fires are not to be extinguished, villains restrained, or watches set by clocks.

When we are entangled in the exigencies of daily life we obtain very fractional and blurred glimpses of things. We note only such first impressions as we need to classify the objects or to hasten on to fitting responses. The artistic beholder, forgetting himself and his needs, stops to take in the object in all its wealth of interesting detail. In free esthetic creativity, the mind discovers a host of picturesque qualities of colors, lines, spaces, forms, tones, which are veiled by business preoccupations. It is the artist who most clearly apprehends the concrete plenitude and possible perfections of the world about him, and preserves his visions in works of art, which may stimulate richer sensuous and emotional life in others also. Emotions, like perceptions, when freed from practical demands, may develop more luxuriant forms and enter into novel alliances. For these reasons, a work of art invites us to unhurried contemplation in the expectant spirit of an adventurer and an explorer.

Art thus transports the sensitive beholder into a world where creative mind transfigures matter to express its rich insights. These illuminating touches of the artist, this evidence of human purpose and artifice, are prerequisites of works of art and a capital source of their charm. These marks allure us to seek the stirring vision which the triumphant artist experienced in producing the work of art. The emotion which moved him may come to be experienced vicariously in the soul of the beholder. Thus works of art,

especially those called great, possess a quality of social investment, appeal, or communicability. They are a kind of symbolic language picturing emotions which, in great art, are potentially universal. Thus *The Thinker* of Rodin (Figure 27) expresses in clear and satisfying form the desperate struggle of a strong man's soul. The muscular figure shows no lack of physical power, but for the moment the universal problem of obtaining bread has forced him into a state of reflection so intense that his toes grip the ground. Such a masterpiece enables the beholder more deeply to appreciate the kinship of all human beings in the face of the perplexities and disappointments of life.

The humanistic aura is lacking in natural objects, such as butterflies and birds, mountains and seas. Whatever species of charm they inspire will be largely a function of one's metaphysics. If one finds that " nature is the art of God " (Thomas Browne), they may have a beauty analogous to man's creations, with an increment, perhaps, of sublimity. Charles Lalo, a distinguished French esthetician, believes that " nature in fact has esthetic value only when viewed through an art, when translated into the language of works that are familiar to the mind and fashioned according to a technique. . . . Art is stylization, and nature without style is non-esthetic." [2] " Assuredly we have no guarantee," declares Roger Fry, a great English critic, " that in nature the emotional elements will be combined appropriately with the demands of the imaginative life." [3] But the artist usually loves nature, at least because she supplies him with an infinite variety of suggestive forms. He never merely imitates or echoes her, but selects, emphasizes, organizes, transforms. Her gifts are transmuted in the spectrum of his personality, infused with the tints, melodies, and flavor of his spirit. Out of the infinite possibilities of the marble block the sculptor fashions that specific perfection which he imagines, and out of the countless colors and shapes of the visual world the painter composes the design that delights him. The artist " bends reality into the direction of a dream, and then endows his magic dream with the constraining power and savor of reality." [4]

A definition of art evidently should include the two complementary aspects of subject and object, of creative experience and created work. The objective phase of art is the more obvious and accessible; the personal aspect, however, is the primary and fundamental aspect. *The art experience is a stirring activity or emotion finding unified symbolic expression in a more or less adequate sense medium.* A more exact definition, perhaps,

[2] Lalo, Charles, *Notions d'esthétique,* Paris, Alcan, 1925, pp. 5 and 9.

[3] Fry, Roger, *Vision and Design,* New York, Brentano, 1923, pp. 37–38; quoted with permission of publishers.

[4] Delacroix, *op. cit.,* p. 447.

is that *a work of art is an individual perceivable form skilfully moulded in fitting material by a creative personality to give an expression or embodiment, as harmonious and self-sufficient as possible, to some moving idea, vision, or wish.*

3. Classification of the Arts and Esthetics

The sense organs which are active in all art furnish a good basis for classifying the arts. While only the eye and ear function directly in the fine arts, other senses supply a fringe of suggestive imagery, as when we speak of a warm or soft color, a sweet or smooth tone, a strong and vigorous line. In the following table [5] the arts which are most complex psychically appear in the visual-auditory division. Opera stands last; it synthesizes nearly all the great arts, and, therefore, may make a very powerful appeal.

Table XIV. A Classification of the Fine Arts

I. FINE ARTS:

A. visual arts (arts of space for the most part):

1. Two-dimensional arts, involving lines, light, color, form, and motion in two dimensions:
   - a. Without motion: *graphic arts:* painting (oil and water color), drawing (etching, lithography, pastel, pencil, etc.); block and other printing; manuscript illumination; stained glass, mosaic.
   - b. With motion: *kinematic arts*: clavilux, motion pictures, fireworks.
2. Three-dimensional arts:
   - a. Without motion: *plastic arts:* sculpture, relief, and intaglio.
   - b. With motion: *dance:* pantomimic, interpretative, etc.
3. Integral arts, combining surface and plastic effects: *architecture* and its landscaping.

B. auditory arts (arts of time):

1. Art of tones: *instrumental music:*
   - a. Produced by single instruments: piano, organ, violin, etc.; whistling.
   - b. Produced by combinations of instruments: concert band, symphonic orchestra, etc.
2. Art of words: *poetry* (*i.e.,* literature possessing rhythm):
   - a. Metrical: verse.
   - b. Non-metrical: prose: short story, novel, etc.
3. Integral arts of tones and words: *song,* chant, oratory.

[5] The main divisions are adapted from Külpe, O., *University of Toronto Studies, Psychological Series,* 1907, Vol. II, p. 217.

C. VISUAL-AUDITORY ARTS:

1. Art of gestures and tones: *choreographic art* (dancing with musical accompaniment).
2. Art of gestures, words, and scenery: *drama.*
3. Art of gestures, words, scenery, and tones: *opera.*

II. MINOR ARTS (with decoration subordinate to utility; standing midway between fine and useful arts):

A. Jewelry: work in gold, silver, bronze, pewter, ivory, gems, etc.
B. Furniture making.
C. Pottery and glass.
D. Textiles: tapestry and rugs; embroidery and lace; etc.
E. Leather work; *e.g.* bookbinding.

This classification of the arts indicates well the field of esthetics. *Esthetics is the philosophical study of the human experiences connected with the fine arts, with beauty, and with taste in all their relationships.* Its purpose is to bring order and understanding into the multitude of bewildering phenomena covered by the word *beautiful* taken in the widest sense. Its pursuit requires the rare combination of keen sensibility and clear thinking, cultivated taste and logical rigor. Oftentimes one of these abilities outstrips the other, and mediocre or bad theories are then likely to result. The esthetician usually starts from personal experiences that are abundant and ever renewed, and seeks, by critical analysis and interpretation, to establish generalizations that are illuminating and conducive to a fuller enjoyment of art. The origin, nature, and varieties of art have been reviewed above. We shall now consider the methods of esthetics, and then proceed to discuss the forms and marks of esthetic experience.

4. The Methods of Esthetics

The advancing science of esthetics welcomes every method that promises insight. A summary follows of the four standpoints which seem most illuminating. In each, the common elements of scientific procedure are assumed to apply: observation and analysis, induction and verification. If esthetics be defined as the general criticism of art, then the following standpoints represent also fruitful kinds of criticism. *Criticism in general means reasoned exegesis and appreciation in the light of the critic's relevant knowledge, standards, and taste.*

(*a*) Technical Criticism. — First in order is technical criticism, which arises from the fact that each artistic medium has its own peculiar properties and corresponding range of possibilities. These peculiarities call for specific forms of proficiency in execution, and have their proper criteria of

accomplishment. *Everything that pertains to execution or performance, to the detailed mastery of material, is called technique.* " It is the machinery and manner of expressing and conveying one's emotion. We expect a satisfying work of art to exhibit a high order of technique, the craftsmanship of an accomplished workman." We may distinguish two phases in art production which a technical critic may study.

First of all, the critic considers the nature of the materials which the artist has chosen as his medium of expression. It is assumed that the technological problems of preparing the materials have been solved. In this task science and industry greatly aid the liberal arts, as in the making of pigments, musical instruments, or buildings. A mechanical invention may bring some new material under artistic control, as the clavilux has successfully employed moving color-light combinations on a splendid scale. The technical critic may inquire whether the expressive possibilities of the medium have been fully exploited, and with what degree of success.

Next, he endeavors to describe the style or manner of expression which the artist has actually used in building up the work in question. He will note whether the artist's treatment of his subject is conventional, variant, or novel. Any obtainable information concerning the training and peculiar working methods of the artist may help to understand his finished product. The worth of a critic's judgment increases as he is the more sensitive to the special conditions, limitations, and criteria that are imposed by the medium and the manner adopted by the artist.

> It is the kind of criticism which, in discussing painting, comments on composition, on the balancing of lines and masses, on the saturation and relation of colors. In poetry, again, this class of criticism is concerned with, *e.g.,* the disposition of vowel- and consonant-sounds, of assonance and rhyme and rhythm and meter. Music, in its turn, has its own jargon. " Technical " criticism is necessary and valuable in that it directs attention to the elements in art and their relation to the structure of the whole; without such accurate discriminations, appreciation would be a much more vague and nebulous thing.[6]

(*b*) Historical and Sociological Methods in Esthetics. — Fine art is more than clever craftsmanship, as personality is more than body. It has soul, the imaginative ideal wrought out of the life of the artist, and dimly reflecting a vast social environment. The artist has a spiritual biography, and his art has a history which may run back to primeval playthings. These aspects of art need the powerful searchlight of historical and sociological criticism. The potency of historical method is due to the in-

[6] Reid, L. A., " Intellectual Analysis and Aesthetic Appreciation," *Journal of Philosophical Studies,* 1926, Vol. I, p. 208.

structive evolutionary perspective into which historical comparison often throws individual creations. Comparisons between epochs, countries, or artists, between kinds and stages of art forms, or between individual works of the same artist, bring to clear light the characteristics of each. Contrasts, variations, and similarities appear which enable the searcher to perceive and grasp esthetic values and tendencies, and to derive, perhaps, general principles of interpretation. The presuppositions furnished by historical knowledge serve, says Croce, as " wood to burn in the fire of the imagination," as " data for the imaginative reproduction " of art, so that the intuition of the artist may become living in the beholder also, become his own history and personal expression.

(*c*) Social Influences in Art. — An important way in which historical criticism helps to explain art is in determining how various social influences have affected the points of view of artists. In the artistic work, the historical observer may discern intimations of race and climate, of national and social culture. He seeks to ascertain how art is causally related to the utilitarian, political, moral, religious, and other phases of civilization. Centuries of collective thought and effort stand between an African tomtom and a Beethoven symphony, between a wigwam and a steel-ribbed sky-scraper. As a medieval Gothic cathedral with its unknown architects comes from the heart of a community devoted to the service of a vast ecclesiastical hierarchy, the sky-scraper is a fitting expression of the modern concentrated business of a congested American metropolis. The major influence in American art has been the discovery and portrayal of the romance of common life, and the minor one, in painting, the representation of alluring landscapes to satisfy our need for repose and relief from a too strenuous life. The sky-scraper is America's greatest and most characteristic gift to the art of the world.

The greater the artist, the more susceptible is his art likely to be to the human aspiration of his own times. He may bring the nebulous longings of his fellowmen to brilliant focus, and thereby turn them into more potent causes in social evolution. The more elemental the theme he beautifies, the surer are his views of being some time universally accepted by those whose visions and sympathies he enlarges. Thus, " Art is the Ark of the Covenant in which all ideals of beauty and excellence are carried before the race." [7] Then, if we wish to know the sociological and spiritual history of a people, their art will be an indispensable index.[8]

Anthropology in recent years has built a vestibule to history which

[7] From *The New Decalogue of Science*. Copyright 1922–1923. Used by special permission of the publishers, The Bobbs-Merrill Company.

[8] *Cf.* Bell, Clive, *Art* (ed. 2), London, Chatto and Windus, 1924, p. 97, and elsewhere.

abounds in exhibits that elucidate the springs of art in the race. An important result is the theory that " art has its origin, almost without exception, in social relations; it has developed under social pressure; it has been fostered by social occasions; it has in turn served social ends in the struggle for existence." [9] We must look for the beginnings of art in dances, mimes, and songs, in festivals and ceremonials with their accompanying devices and decorations. These, however, developed with constant reference to the needs, pleasures, and approval of the group.

(*d*) The Search for Historical Movements. — Another opportunity of historical criticism is to discover and verify general movements or uniformities in art. By tracing the vicissitudes of art in related times and places, hidden tendencies, perhaps barren or fruitful, may be discerned. History shows, for example, that the school of Raphael (Italian, 1483–1520) led into a blind alley of imitation, while Paul Cézanne (French, 1839–1906) originated " methods and forms which reveal a vista of possibilities to the end of which no man can see."

A number of interesting tendencies are formulated in that part of Lalo's book which deals with " sociological esthetics." Thus, a survey of decorative styles shows, he declares, that normally they do not flourish for more than one generation. Then there is the *rule of originality,* the aversion to copying, the universal quest among artists for new forms. " Each generation fitted to live esthetically prefers naturally something other than precedent." [10] The *triadic cycle* is another type of regularity that occurs in uninterrupted periods of artistic development; namely, the evolution of an art through formation, maturity (classical age), and decadence. " The principal characteristics of these three phases are the purity of tastes, the probity of techniques, the separation of kinds, and the clear and rational character of composition in the classical ages; the abuse of mixtures, of impurities, or of complicated effects and of more doubtful taste in the two extreme ages." [11] The painting of the Italian Renaissance and the Elizabethan drama furnish notable examples of such cycles. Uniformities of this sort, established in well known arts or epochs, provide forms that are suggestive guides in investigating other periods.

Historical surveys serve to identify art forms that are more or less classical and enduring. The student is under obligation to know their characteristics. Schools and academies tend to thrive around widely esteemed forms. Invariably, however, a younger generation revolts against academic restrictions and strives for progress by creating other forms.

[9] Tufts, J. H., " The Genesis of Aesthetic Categories," *Philosophical Review,* 1903, Vol. XII, p. 1.

[10] *Notions d'esthétique,* p. 93.

[11] *Op. cit.,* p. 94.

Disdainful of conservative opposition, they hope for renown in the eyes of another or later public, perhaps more unprejudiced and wiser, whose taste they seek to anticipate or shape. "The ideal is the normal that is future or considered better in a superior moment of evolution." [12] The dissenting artists assume the risk of condemnation and oblivion, for their forecasts have all the inconveniences and possibilities of hypotheses. Art history thus shows the imperative need in the critic of an open and sympathetic mind towards variations and innovations, however preposterous they may seem at first.

Among the valuable sources of data for historical, and also psychological, study are the varied writings by and about artists, critics, and connoisseurs. The works of such men as Leonardo da Vinci, Goethe, Schopenhauer, Richard Wagner, Matthew Arnold, Rodin, and Santayana teach much concerning the dynamics and ideals of artistic creations.

The history of art thus provides a background against which we may more surely evaluate and appreciate particular works and tendencies. The aim of historical and sociological methods, in short, is to trace the evolution of artistic works in different ages, countries, and individuals, and to define the causes and aims necessary to explain their development.

(*e*) Psychological Methods. — The history of esthetic experiences in the individual is a psychological problem. The study of this problem makes up much of recent esthetics. The psychologist seeks to describe and explain exactly and fully all mental phenomena associated with the fine arts. He is especially interested in the detailed motives and moods, perceptions and imaginings, which condition the creation and enjoyment of artistic works. The psychic background thus delineated contributes to an intelligent criticism of art. Several phases of psychological method may be distinguished.

First comes the psychogenetic search for the instincts, interests, and environmental influences which give rise to the artistic impulse. Child psychology also yields suggestive information concerning the development of the art impulse. Psychoanalysis has shown that artistic works, like dreams, mythologies, and other imaginative products, are manifestations of deep human desires which here obtain a more satisfying outlet than in practical life. The social psychology of art aims to describe the many subtle social factors in its creation and appreciation.[13] Art gives concrete interpretations to man's passions, defects, and hopes, which may deeply influence his conduct.

Psychological criticism includes also an analysis of the physiological

[12] *Op. cit.*, p. 23.

[13] *Cf.* Hirn, Y., *The Origins of Art: A Psychological and Sociological Inquiry*, London, Macmillan, 1900.

factors in the enjoyment of art. Various bodily functions condition esthetic satisfactions. Thus, an appreciation of rhythm in the temporal arts is influenced by the rate of breathing, heartbeat, and muscle functioning. The undulatory eye movements stimulated by a serpentine line of appropriate size ordinarily is much more pleasing than a monotonous straight line or a jolting angle. The principles of balance are essential to art because they are essential to human beings who have risen from four-footed locomotion to a delicately adjusted life on two feet.

Having done our best with analytic criticism, we wish to attain a more synthetic personal insight, which is excellently signified by Henri Bergson's definition of intuition: " By intuition is meant the kind of *intellectual sympathy* by which one places oneself within an object in order to coincide with what is unique in it and consequently inexpressible." [14] This tendency to project ourselves into artistic creations has been put forward as a universal mark of esthetic value under the name of *Einfühlung* (variously translated: empathy, introjection, autoprojection, symbolic sympathy). It is illustrated by the feeling of secure restfulness inspired by horizontal artistic lines, or of elevation in beholding the upward sweep of a lofty spire or nave. While this quality of autoprojection fails to be distinctive of the esthetic, in that it applies to other perceptions also, it reminds us that there is a dynamic factor in the experience of the beautiful.

(*f*) Experimental Esthetics. — Psychological students of art employ experimental controls whenever possible. Up to the present experimental esthetics has been concerned largely with the study of simple art forms, such as geometrical lines and figures, combinations of points, surfaces, colors, and tones, problems of rhythm, etc. This method was founded by G. T. Fechner (German, 1801–1887), who devised several ingenious tests for measuring esthetic pleasures. Noting, for example, that rectangular shapes are widely used for windows, panels, pictures, books, etc., he asked what pure rectangle would be most pleasing when abstracted from its practical context. On cards he drew squares and rectangles of many proportions, and then requested numerous observers to select the ones they liked best. The facts thus collected were statistically organized and an average or normal type of taste was exactly defined. He concluded that the sides of the most pleasing rectangle are related as 1 to 1.618, 13 : 21 or 5 : 8 being satisfactory approximations. This result may be stated in a precise mathematical formula, called mean and extreme ratio: $a : b :: b : (a + b)$. This proportion has been called the " golden section " or mean. It has extensive applications in the visual arts.

[14] *An Introduction to Metaphysics* (trans. by Hulme), New York, Putnam, 1912, p. 7. Reprinted by courtesy of the publishers.

Lalo points out that " in the simplified figure one achieves the maximum of diversity compatible with the maximum of unity. Among the forms most generally disliked, the square offers much unity but little diversity, whence come monotony and heaviness. The square that is slightly deformed and the very long rectangle present much diversity but little unity in their lateral relations: whence arises lack of harmony." [15]

The experimental study of simple forms, however, has very restricted value because these forms conserve slight artistic value when separated from the context of concrete works of art. " The best laboratories of experimental esthetics remain the workshops and studios of artists, or the libraries, theaters, and museums." [16] In entering into and apprehending those inner synthetic phases of esthetic experience which may overflow and elude a strictly objective psychology, we find that the philosophical approach comes to our aid.

(*g*) Philosophical Criticism and Problems in Art. — Philosophical criticism is the culminating phase of art study. It coördinates the basic results of other methods and strives for a more complete synoptic view of the nature of art and beauty. In the medium of the philosophic spirit, science and art, the thinker and poet, may be allied, sometimes joined. As philosophy may pervade great poetry, literary beauty may ornament great philosophy. The self-sufficient but limited wholes in which the artist expresses his vision of things resembles the unified and total view which the philosopher aims to achieve. The one puts first expression of form intuitively felt, the other, principles and concepts rationally integrated. The one realizes the coherence of a permeating form or emotion; the other, the consistency of an articulated system.

The philosophic esthetician makes bold to amalgamate these ideals, which actually are not abstractly separated. He requires his explanations to justify themselves by leading to a fuller grasp and appreciation of esthetic reality in its rich individuality. Philosophy, in short, is at once comprehensive and concrete, synthetic and normative. It strives to illuminate the individual work by setting it in the perspective of the whole context of life. This kind of apprehension is precisely what we desire most for artistic works.

Whatever failure or success the philosopher has in knowing clearly the meaning of the esthetic life, he nevertheless insists that the personal values in art shall not be distorted or lost in formal scientific analysis. We have already cited an example of this insistence, in Bergson's protest against a static intellectual view of reality. The philosopher is persevering in his quest for an understanding or standpoint that will bring him back to a more perfect realization of esthetic values. " When the poetic imagination

[15] Lalo, *op. cit.*, p. 15. [16] *Op. cit.*, pp. 16–17.

restores philosophy to immediacy, human experience reaches its most exalted state, excepting only religion itself." [17] Besides progressive analytic criticism, the philosopher may employ the method just suggested, which may be called intuitive, esthetic, or simply philosophic.

The nature and varieties of art and the methods of esthetics, already discussed, are only a part of the task of a philosophy of art. Other concepts which need examination are: artistic creation, the norms of beauty, taste, style, classicism, romanticism, criticism itself, the nature and functions of special arts, etc. The philosophical esthetician, in short, tries to determine the principles of esthetic experience in all its varieties. A notable attempt to do this is found in the system of Charles Lalo.[18] He believes that *harmony, working through the play of the imagination, is the fundamental law of esthetic life,* and that all esthetic types may be organized under this law.

The philosopher also endeavors to exhibit the place of esthetic values in the wider system of human interests, and to show their relations to such other values as economic, recreative, intellectual, moral, and religious ones. Finally, he seeks to indicate the relation of art and beauty to the evaluating self, to society, and to reality, and thus strives to show their place in a total view of life and the world.

(*h*) Art Criticism and Philosophy. — In order that the critic may not lack the experience of art in himself, it is desirable that he be a creative artist in some important medium. Of great advantage, also, is discussion and association with artists and art critics who have achieved rich experience and refined judgment. Their candid preferences and testimony concerning the merits and defects of artistic creations are significant and valid guides for those of lesser relevant knowledge. Under such tutelage others may attain higher levels of taste and esthetic life. *By taste is meant a more or less discriminating and lively appreciation of beauty.* It may be generated under the subtle influences of personal contact with creators and connoisseurs in action. One learns to enjoy by seeing and hearing how qualified judges enjoy themselves in the presence of satisfying works. It is the union of intimate appreciation of individual creations with capacity for exact and illuminating generalizations concerning them that distinguishes the great esthetician.

After the art critic has done his best to communicate his estimate, he may finally be able to say only: " Behold, I revel in that, do you? " Some learners may yet remain cold, sightless, discordant, even pained. Under these circumstances there is no appeal beyond the individual's taste at the moment, for one's liberty of preference must be respected. Two provisions,

[17] Perry, R. B., Ch. 2, " Poetry and Philosophy," in *The Approach to Philosophy,* New York, Scribner, 1910, p. 52.

[18] Lalo, *op. cit.,* pp. 57–64.

however, need to be hastily added to this declaration of freedom. The first is that taste may be cultivated. This possibility is an important stimulus to the work of estheticians and educators. The other provision is that those persons who possess a wealth of experience and who cannot repudiate the discovered joys of fine art are likely to be the best judges and authorities for those who have not experienced those joys.

(*i*) The Individual and the Universal in Art. — It is often questioned whether general principles and standards are possible for works of art, since assuredly they possess individuality. The peculiar temperaments and aspirations of their creators are melted into their essential textures and give them *that unique blend of personal qualities called style which is difficult to imitate and charming to behold.* But although individuality and originality are usual accompaniments of excellent art, these already are general conceptions. Various general principles result also from biological and psychological studies of the universal mental factors which are present in artistic creation and enjoyment. Other laws arise from the definite properties of the physical media which always condition art. An analysis of the slits in the rolls of the Duo-Art player-piano has led to a general explanation of the stylistic variations among noted pianists in terms of a few determinate kinds of temporal note combinations.[19] Artistic works, then, have both an individual and a universal aspect.

These two phases of art are reflected in *the twofold motives in artistic creation.* The first is that of *expression,* an impelling desire to express what one has felt or seen. The remarkable etcher, Blanding Sloan, has put down among his maxims: "to desire with relentless energy which subsides only with soul-satisfying creation; to try for the exhilaration of allowing impulses to flow, though naturally, into untrammeled form."[20] The second is the *form motive,* the struggle for beautiful form so as to perfect, objectify, and perpetuate one's emotion. The possession of technical mastery in a particular medium may itself constitute an urge to further exercise and invention. In the achievement of adequate and abiding symbols, one's expression becomes freest, ever renewable, and also subject to the judgment of others. Thus transitory and private ideals may become the immortal treasures of the race. Soul and pattern, feeling and intellect, therefore, are united in all art, and both admit of comparative study and generalization. Esthetic philosophy is possible because of this element of reason that permeates art.

We have now completed our review of the methods of establishing

19 Whipple, G. M., "A New Method of Analyzing Musical Style by Means of the Reproducing Piano," *Journal of Applied Psychology,* 1928, Vol. XII, pp. 200–213.

20 *Etchings and Block Prints of Blanding Sloan,* San Francisco, Jonck, Kibbe and Co., 1926, p. 52.

esthetic principles. These principles fall into two main groups as determined by special and by general esthetics. The first contains the more particular laws and criteria of the special arts. Examples of these are the rules of perspective and color combination in painting, of rhyme and rhythm in poetry, and of harmony in music. Space forbids any account of this interesting and important group. The second embraces the more general principles which are valid for many, if not all, kinds of art. In the concluding sections we shall summarize some of these, to which all of the methods described above have contributed.

5. Expressionism in Contemporary Art

Let us return for a moment to the important distinction between form and expression in art creation. The term *expressionism* is applied to one of the most vigorous and multifarious of "modern" movements in art. In the realm of painting, expressionism goes back to the brilliant innovations and tireless experimentations of Cézanne.

Contemporary expressionists commonly interpret reality in terms of energy (energism). They project themselves into nature and feel intensely its pulsing energies. At the same time they strive to create new artistic forms which will more adequately express that structure and strange dynamism of existing things which are invisible to the common eye. They scorn imitation and superficial representation of objects as they appear to the senses. They break up what they perceive or imagine into crystal blocks and colored planes. They distort and reconstruct, and thus manifest at once their mastery over their material, their powerful emotions, and the mighty forces which operate in nature. They despise trivial ornament, tedious detail, and everything that savors of weak sentiment. They abstract the significant geometrical forms of natural objects and strive to rebuild them in such rhythmic masses as will suggest the competing and tumultuous forces that live in them.

The expressionistic movement today is perhaps strongest in Germany. To illustrate this movement we may consider briefly the art of Lyonel Feininger. Although he is an American (born in New York City in 1871; trained in Germany and France), he has spent most of his life in Germany. He is one of the greatest living cubists. Cubism is one of the most vigorous phases of the larger movement of expressionism. The cubists disregard the usual appearances and associations of objects, and endeavor to exhibit their bare structural skeletons in rhythmic compositions. They may even discard this effort, and independently create geometrical symphonies out of simple space forms.

Feininger is notable for his strong feeling for architectural values and

Fig. 26. A Woman's Head

Lyonel Feininger, 1916. (In the collection of Erich Mendelsohn, Berlin.)

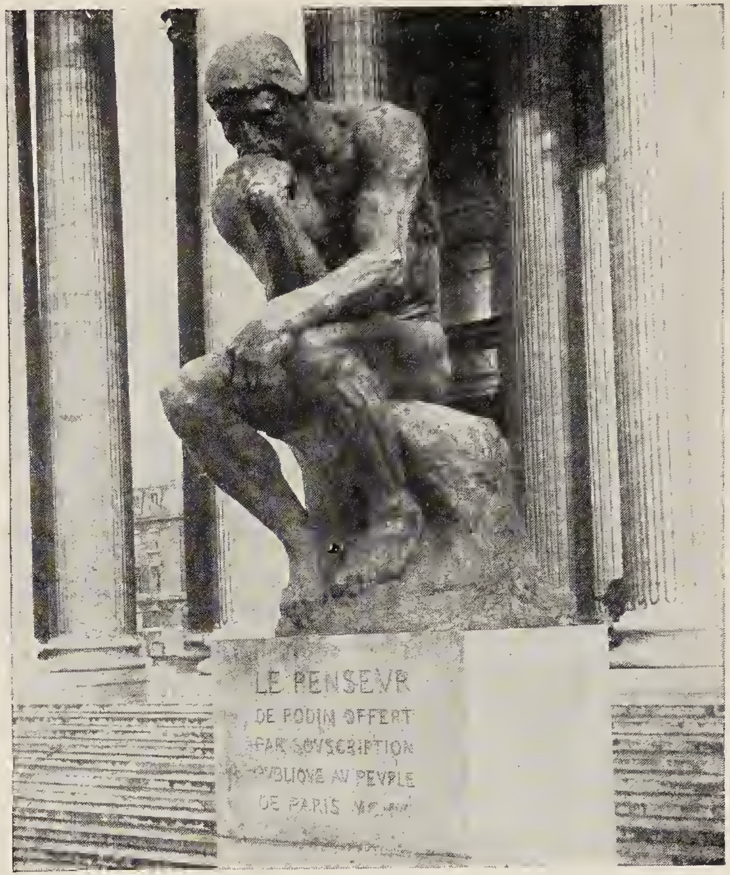

Fig. 27. The Thinker

Auguste Rodin (French, 1840–1917).

Fig. 28. The Sistine Madonna
Raphael Sanzio (Italian, 1483–1520).

for his original caricatures and fantasies in spatial articulations. The cubical analysis of objects fascinates him; and he is fond of playing with beautifully shaped planes and polished crystals refracting subdued colors. Not only in buildings and ships, but in clouds and living beings, he sees architectural forms: fanciful towers and lovely triangles, sweeping curves and transparent surfaces. In Figure 26 we see an architectural portrait of a woman which has charming originality and its own peculiar unity and massive rhythm. A reproduction, unfortunately, does not suggest the reserved colors which Feininger skilfully harmonizes to enhance the geometrical qualities of his creations.

6. Some Norms of Beauty

(*a*) Unity in Variety. — With a view to defining the beautiful, we shall now describe several norms or criteria which express certain universal characteristics of a satisfying work of art. We must ignore here the numerous species and degrees of the beautiful. We shall first ask: What are the ideal qualities or form which make a work of art satisfying? Our provisional answer grows out of the individuality which an artistic creation always is. Individuality means a concrete unified whole. Along with a certain richness of contents, it has a measure of internal coherence. *Unity in variety* is the most fundamental norm of beauty. Other norms follow from this one.

A beautiful object is a determinate and pleasing synthesis of interesting and varied materials. It avoids at once extreme simplicity and extreme heterogeneity. The first is monotonous and unstimulating; the second, perplexing and distracting. An enjoyable work needs enough complexity to invite exploration but not so much as to weary our limited powers of attention. The recognition of sameness amid difference, the modification of forms that have been perceived before, is a perennial source of charm in a work of art. An artistic work is composed of details which are sensuously agreeable, imaginatively suggestive, and emotionally attractive. On the other hand, these should contain enough clarity to allure to orderly contemplation. Its self-sufficient and vibrant harmony should prevent any sense of need for going outside to complete it.

Ugliness exists in some objects because they have diversity without coherence. They remain as problems in organization which the designer has failed to solve. Their parts sprawl and straggle loosely about without an inner purpose to draw them together. Their "aimless zigzagging" fails to give coördinated wings to the imagination and is oppressive and disagreeable. It is the triumph of rhythmic arrangement over anarchic variety that engenders the greatest esthetic enjoyment and that leads us to pronounce anything beautiful.

(*b*) Unifying Theme and the Principle of Subordination. —

The work of art originates when the artist calls forth a concrete order out of the chaotic multitude of possibilities — lines, shapes, tones, colors, movements — that confront him. Leaving, so far as possible, the stereotyped things with which abstracting intellect has peopled the conventional world, he abandons himself to the primitive flood of unclassified experiences, and strives to tame their wildness anew by weaving into them such form and rhythm as pleases his free imagination. He proceeds by progressively omitting, isolating, and simplifying materials according to the delight of his momentary feeling and fancy. The unifying deed does not occur until he visions the more or less distinct outlines of a harmonious design that promises satisfying expression. His initial discovery may be a simple musical refrain or pattern of colors, a poetic sentiment or a tragic heroine. But it gives him the directing idea for designing and developing his work, and provides a touchstone of congruity and emphasis. Some presented elements instantly sink into oblivion, while others leap forward to crystallize into significant pattern. These cease to be discrete identities and are now felt as reciprocal modes of a new qualitative whole.

From this genetic account of unity in variety two other requisites of every perfect work of art may be derived: it embodies a *dominant form or theme,* and with reference to this form there is a *just subordination of elements.* In the following section, after a brief description of unity in general, we shall indicate some ways in which variety in unity is made delightful.

(*c*) Types of Unity in Variety: Balance and Evolution. — In the creation of art the attainment of self-explanatory unity is, as we have seen, of fundamental importance. We recognize the unity which the artist has experienced when, on reflection, we perceive that the diverse elements of a work of art concur in perfecting the whole, and that they are at once indispensable and adequate. *In esthetic enjoyment,* apart from critical intent, *unity means a harmony of qualities immediately felt, a form that may be apprehended as a self-sufficient whole.* A beautiful work possesses definite and psychically fitting limits in time or space, as a painting has its insulating frame, and a drama a proper beginning and an end not too remote. This ideal of harmony excludes anything that is irrelevant, superfluous, or incongruous.

> Unity in variety may exist in any one or more of three modes — harmony or union of coöperating elements; the balance of contrasting or conflicting elements; the development or evolution of a process towards an end or climax. The first two are predominantly static or spatial; the last, dynamic and temporal.[21]

[21] Parker, D. H., *The Principles of Aesthetics,* Boston, Silver, Burdett, 1920, pp. 86–87; quoted with permission of publishers.

A few types and examples of static unity may be noted. A dominant material may provide unity, as when a single hue, such as blue or green, suffuses a painting with a nocturnal or misty atmosphere. An inclusive space-form, for example, a pyramid or an ellipse, may unify the work. Again, an architectural structure may be held together by the repetition of an ornamental form, such as the round arch and window. Indeed, repetition of motives is used widely in the arts as a principle of unity, notably in music. In radial symmetry the same relations stream out repeatedly from a center, as in rosettes and other patterns conventionalized from flowers, starfish, and similar things. In bilateral symmetry, color masses are deployed at similar distances on both sides of a middle line. Sometimes a brilliant spot of color or a relatively small object may be set over against the rest of a picture because of the intense psychological interest it arouses. An example of this " occult " or psychic balance is found in the picture of an Alpine climber in a perilous position over against a great mountain.

The various symmetries that have just been indicated are really species of balance, for they exhibit differences in direction, of right and left, above and below. " *Balance is equality of opposing or contrasting elements.*" [22] It means that one element is adjusted to offset another answering or complementary one, in consequence of which fact any modification in one factor demands a remodeling of the whole. Balance, in short, means that " even weights — size, color, interest, anything — are placed on either side of a center."

In the temporal arts, unity in variety is achieved through rhythm and evolution. " Rhythm is the ordered succession of variations of accent and emphasis." [23] It is the balance of time, the symmetry of movements. Examples of welding agencies are found in the meter, rhyme, and refrain of poetry, the iteration of a musical melody, the reappearance of a dramatic hero, or the recurring movements of a dance. In the sonnet a definite system of accents and rhymes, coupled with a single pervading mood doubly expressed, binds the whole together. In the drama, opera, and novel, unity in variety attains its most elaborate and intellectual form. They develop to a necessary climax and conclusion through a causal sequence of human actions and interactions. For obvious psychological reasons, however, the development of a theme must be neither too complicated nor too rapid, neither too easy nor too slow. Fitness and proportion are ever the breath of life in art.

In all arts striking balances may be realized by the method of *contrast.* Sometimes this approaches the forbidden land of unmitigated conflict and

22 *Op. cit.*, p. 38.

23 Hamlin, A. D. F., " Fine Arts," *Encyclopedia Americana,* 1925.

contradiction. When realized in lesser degree, contrast may greatly stimulate interest and delight. When brightness and shade, poverty and pomp, humor and pathos, are brought together, they both intensify and relieve one another, and, in so doing, coöperate in producing a more fascinating whole. In tragedy, the pleasure of the spectator is enhanced by the tinge of pain, and the essence of comedy is the sudden union of factors that had seemed incompatible. The combination of rhythm and arhythm, the fresh modulations of contrasting forms, is an important characteristic of great art.

(*d*) Volkelt's Norms. — Volkelt has attempted to summarize in four norms the marks of a work of art which is esthetically satisfying.[24] Each of these norms is twofold: the first part refers to the object or work of art, and the second, to the subjective aspect of the experience which it stimulates in the beholder. His norms are as follows:

(1) A satisfying work of art (*a*) expresses harmony of form with content, and (*b*) is emotionally picturesque: our contemplation of it is permeated with satisfying feeling.

(2) It (*a*) exhibits a plenitude of human significance, and (*b*) enlarges our emotional life.

(3) It (*a*) inducts us into an ideal world of imagination, and (*b*) releases us from the sense or tension of everyday reality.

(4) It (*a*) presents an organic whole, and (*b*) stimulates the mind to mental synthesis.

(*e*) Obstacles to the Experience of the Beautiful. — The preceding norms express lofty ideals of perfection which evidently are infrequently attained. Nevertheless, they serve as illuminating guides for lower levels of achievement. The nature and conditions of esthetic experience are so complex that it is easily adulterated, prevented, or destroyed by the substitution of cognate attitudes. The multitude of obstacles that spoil it fall into three groups.

First, the experience of the beautiful is easily supplanted by exclusive concern with *theoretical or scientific inquiries*, such as with the truthfulness, authenticity, or historical instruction of a painting, the archaeology of a sculpture, or the psychic conditions of a symphony. Second, *practical questions* may also impede esthetic appreciation; for instance, questions regarding the materials, utility, cleverness, popularity, selling price, or moral effect of an artistic work. Third, there are numerous *emotional distractions*. Examples of these are seen in the quest for pleasure, diversion by familiar associations, the pressure of turbulent or exciting desires, or the

[24] Volkelt, J., *System der Aesthetik*, München, C. H. Beck, 1905, Vol. I, pp. 392–585; *cf.* Wilson, G. A., *The Self and Its World*, New York, Macmillan, 1926, pp. 191–207.

self-conscious enjoyment of one's esthetic experience itself (sentimentalism). When esthetic pleasures are analyzed with reference to their meaning, they pass from pure enjoyment to pure psychology.

7. Summary Description of the Experience of the Beautiful

There are three kinds of substitutes for esthetic experience because it has three distinguishable aspects in which the mind may be enthralled. It is a synthesis of cognitive, emotional, and active factors. We shall now review these phases from the standpoint of the one who responds to an artistic production rather than from the standpoint of the producer.

From the *cognitive standpoint,* the essence of esthetic experience is *contemplation.* It begins with our perceiving and assimilating a work of art. We stop leisurely before it and let it play freely upon our eyes or ears. Its rich colors and patterns, melodious tones, or rhythmic movements spontaneously delight our senses. Its dominant form or theme also invites us to exploration. The whole summons into the fringe of consciousness an alluring aura of associations of mysterious but potent origin. The highest powers of the intellect may be called forth in comprehending the rational order in a great work of art, as in a long poem, a symphony, or an opera. B. P. Bowne has suggested that objects please us esthetically because "the soul is pleased with whatever expresses or embodies or symbolizes its own inner life. Regularity, symmetry, proportion, harmony, please because they accord with and express the orderly nature of intelligence." [25]

In artistic appreciation, however, cognition is not bound to scientific analysis and verification. We become absorbed in the palpable qualities of the object, ignore its inner nature and external relations, and remain indifferent to its truth or falsity. Here cognition is wholly devoted to liberating and entertaining the imagination. The realm of the fine arts is the playground of the human mind, a paradise of make-believe brought to perfection. But we can enjoy this world of treasures that has been prepared for us only as we spontaneously and fully recognize and recreate them for ourselves. The essence, then, of esthetic contemplation is this: letting a beautiful individuality, with all its suggestive form and luxurious ornament, live and develop through our responsive senses and imagination.

Esthetic contemplation is deeply tinged with emotion: detached, unrestrained, sometimes ecstatic. From the affective or *emotional standpoint,* esthetic experience is the *serene enjoyment* of beauty. In the appreciation of a beautiful production, the sentiment objectified and incarnate in it is to some extent reproduced in the soul of the beholder. Its sensuous qualities

[25] From Bowne's *Introduction to Psychological Theory,* pp. 203–204. Copyright. By permission of American Book Company, publishers.

themselves have an affective value; we speak, for instance, of restful or gay colors, of sad or cheerful rhythm in music. The harmonious form of the object finds its complementary response in a fresh emotional synthesis. This dominant mood is sometimes made richer and more intriguing by a component of pain, as when in tragic art the worth of a human wish is exalted through the presence of opposition, defeat, or loss. The emotional power of an artistic work is increased when it gives expression to those elementary feelings which are potentially universal among men; when, for example, the familiar is idealized or the uncommon is reported in intelligible symbols.

A work of art, then, should enlarge and organize our emotional life. The fine arts allure us to new worlds of perfected sentiment, and we attain in some degree a vicarious realization of the artist's vision. Here we come to know in consummate forms the mystery, hardship, or utter serenity of life, its gayety and gloom, romantic love and plotting hatred, splendor, majesty, and intimations of the infinite.

In esthetic experience, too, the mind is active, as ever, in the sense of being alert and alive to the artistic object, in the sense of sustaining exploration and contemplation. Our activity, however, is not an overt response to the demands of duty or expediency. Rather, it is drawn on by the undefined wish to assimilate the beautiful creation to which chance or curiosity has brought our attention, and to attain the delightful harmony of experience which it promises as an advertised work of fine art. Absorption in it releases us for the time being from the sense of personal struggle and anxiety. The hazards and harshness of practical reality do not trouble us. From the conative or *volitional standpoint,* esthetic experience is will absorbed in restful, rhythmic, *self-sufficient activity.*

We have seen how esthetic experience is a complex activity that gives expression to all the functions of personality. It addresses the senses and the imagination, the reason as well as the heart, and moves all our faculties at once. It is a *dynamic harmony of agreeable contemplation.* The artistic or esthetic spirit may beautify and transform any phase of life and confer upon it a new excellence and a fresh charm.

Beauty exists when an appreciative mind is agreeably absorbed in a charming creative form. The artistic work contemplated takes on intrinsic value, is called beautiful, because of its power to stimulate the imagination to exuberant play. Beauty, however, requires both an object fitted for disinterested reconnaissance and a sensitive mind capable of enjoying it. The mind attains feelings of equilibrium and repose as it perceives the unified variety presented in the artistic work. A rich new emotional life freely develops which is circumscribed only by the moment's own delight. At the highest levels of beauty we achieve a self-complete experience, a

taste of finality, and live for a while amid perfections which we would gladly prolong. It is such experiences that esthetic culture should enable us better to realize, and from which the student of esthetics makes his inductive leap.

R. F. P.

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CHAPTER XIX

THE STUDY OF RELIGION

1. Some Aspects of Religion

Religion, like knowledge and beauty, exists as one of the major values of life. It is one of the most natural, paradoxical, and arresting of human experiences. Religious emotions are familiar to most of us; yet our notions of religion, as of art and morals, are for the most part cloudy and superficial. One reason for this common vagueness is that we identify religion with some narrow aspect of experience, whereas it may be as inclusive as experience itself. It seems elusive because it overflows this or that limited concept in which we would thoughtlessly confine it.

The very richness and complexities of religious experience have postponed the acquisition of adequate ideas concerning it. Some persons have failed to emerge from primitive fog because they have falsely assumed that there exists some magical short cut to the knowledge of divine things. The search for a spiritual organ, religious instinct, supernatural sense, or other special faculty for directly apprehending God without the aid of ordinary processes of thought has signally failed. A valid theology is to be won by the same sort of hard intellectual labor as a valid esthetics, politics, or metaphysics. Only the beginnings of a scientific study of religion have been made, however, and efficient methods of investigating it are still in the making.

Most students of religion agree that no experience can be called religious which is not somehow related to a being who is regarded as superhuman or divine. This relationship commonly takes the form of a feeling of dependence upon a deity who is viewed as the ultimate determiner of our environment and destiny, and who bestows upon us certain goods which we need and esteem. It is a social relationship which brings both benefits and obligations. The individual gains moral power by believing in God as the friend of man and by actively participating with Him in building up a divine-human community in which good-will and other spiritual values shall flourish. The soul which at first felt lonely and alien in the world, perhaps even a helpless enemy of God, wins through faithful cooperation a harmony and peace of mind which is novel, satisfying, and invigorating. God comes to be trusted and worshipped as a superior power who is in league with man in producing those goods which he enjoys. " Re-

ligion is a unifying, integrating, stimulating influence that opens our natures to ranges of values that we have been ignoring, because it ties us up to the source of all good." [1]

We have just epitomized some essential phases of a highly developed religious experience. Religion evidently is an expression of the whole nature of man, of his intellectual as well as of his emotional and volitional life. Each one of these three basic factors of human nature has been taken as dominant and made the basis of a definition of religion. The three following types, or combinations of them, include most definitions of religion. Each has its proper virtues, shortcomings, and obscurities.

(*a*) Reason and Creeds in Religion. — While human personality cannot actually be split up, the fact remains that the keenest demands of one person are for knowledge, while others are content with a relative but quickening chaos. Some men are restless in a world they cannot understand. To them the essence of religion is rational insight into the nature of reality; God is the solution of the riddle of life and a resting place for their exploring minds. For example, G. J. Romanes (English, 1848–1894) declares, " Religion is a department of thought having for its object a self-conscious and intelligent Being." [2] James Martineau (English, 1805–1900) defined religion as " a belief in an Ever-living God, that is, a Divine Mind and Will ruling the universe and holding moral relations with mankind." [3] This definition is quite representative of the traditional Christian point of view. The belief that God is the ground of cosmic order becomes a directive, balancing, and invigorating force in the thought and conduct of the rationalist. It issues in an equilibrium and peace of mind which Spinoza, " the God-intoxicated philosopher," called " the intellectual love of God."

Theories of religion have been associated with many views of life and morals which have proved false and turned out to be superstitions or myths. As soon as we perceive, however, that the intellectual conception of religion is only one aspect of it, we see also that these outgrown theories do not destroy religion. Religion, even as reason, cannot be defined as wedded to a particular type of thought. It can be adapted to any view of the world which recognizes that the ultimate power is intelligent.

For these reasons, no particular statement of doctrine or belief can be set up as the sole criterion of religious values. The cruel persecutors of dissenters have quite universally overlooked the fact that a man's conduct may be a surer mark of heresy than his creed. As soon as creed is made to count for more than character religious life is likely to suffer from confinement,

[1] Wilson, G. A.

[2] *Thoughts on Religion,* Chicago, Open Court, 1895, p. 41.

[3] *A Study of Religion* (ed. 2), Oxford University Press, 1900, Vol. I, p. 1.

coldness, and even cruelty. Religion is proved to be larger and deeper than religious belief by the way it continues to flourish in spite of the outgrown doctrines which have been attached to it.

While belief is not identical with religion, it is *an important component* of it. Critical thought makes more or less articulate the nebulous longings of the soul by giving structure to the object of worship and by defining the ideals of life. Reason also may enrich life by devising cults and beautiful rites, creeds and theologies.

In creeds and theologies, individuals and communities may summarize their best thought of the moment concerning the essentials of religion. Historically, creeds too often have been vitiated by the intrenched social prejudice that they are unchanging, final, and eternally true. So many dogmas have proved to be fetishes or errors that it is now the fashion to disparage creeds or eschew them altogether. Some churches profess to be creedless; as a matter of fact they cherish the equivalent of a creed in the form of a lively set of convictions and ideals, but they refuse to state them formally lest they be embarrassed when a doctrine becomes obsolete. In science, we should hardly dismiss the theory of relativity because Ptolemy, Copernicus, and even the great Newton made mistakes in formulating the laws of the solar system.

The scientific student of religion does not claim that his results are final. Rather, he adopts the scientist's postulate of growth and his method of hypothesis. Accordingly, he eagerly anticipates that increase of religious truth which richer human experience and research may yield. He regards even the most perfect formulation of religious insight as a stepping-stone to something better. He so states his creeds that they may be susceptible of continuous growth. He treats all creeds and doctrines as instruments for clarifying and enlarging religious experience. He will not always be content with a single creed. He will want more creeds, many creeds, plastic and inclusive creeds, comprehensive philosophies of religion, in which there is room for all essentials and a welcome for every new insight, however humble or exotic its origin. Creeds, as Lotze suggested, are " like the bones of the body, the outcome of the life-process itself and also the means by which it gives firmness, stability, and definiteness of outline to the animal organism. No universal and spiritual religion could maintain itself without some doctrinal statement of the principles implied in its own life." [4]

(*b*) Emotion and Mysticism in Religion. — The French mathematician, Blaise Pascal (1623–1662), long ago said that the heart has its reasons which the intellect cannot know; and the German poet, Schiller (1759–1805), has declared:

[4] Galloway, George, *The Philosophy of Religion,* New York, Scribner, 1914, p. 165; quoted with permission of publishers.

> "What thou thinkest belongs to all;
> How thou feelest is thine own.
> Wouldst thou make Him thine own?
> Feel thou the God whom thou thinkest."

The best-known definition which makes feeling basic is that of F. E. D. Schleiermacher (German, 1768–1834), "the founder of modern theology." "The essence of religion consists in the feeling of absolute dependence upon God, . . . which is the same as to say a feeling of being in touch with God." C. P. Tiele (Dutch, 1830–1902) has declared that the essence of religion is "that pure and reverential disposition or frame of mind which we call piety. . . . The essence of piety is adoration." He proceeds to describe adoration in terms which bid fair to embrace man's whole emotional life.[5] Harald Höffding (Danish, born 1843) believes that religious need consists in the desire to hold fast and conserve the highest values in the battle of existence. Thinkers of this type regard religion as an expression of man's deep and "ultimate demand for conscious self-preservation" in the weird and overwhelming world in which he comes to himself.

Religious emotion attains rich expression in some forms of mysticism. Mysticism appears with the mind's endeavor to realize the immediate presence of God. In this experience (1) *the intellectual powers tend to be depressed,* for they are analytic and discursive, whereas the mystical experience is marked above all else by (2) *a pervading sense of unity.* Thus, the great Dutch mystic, Ruysbroeck (1293–1381), says, "In this simple and intense contemplation we are one life and one spirit with God." For the time being, the mystic becomes indifferent to the details of sense life and of history: they are partial and superficial; he knows the permanent and the essential, as it were, from within. He is delivered from what is fragmentary and commonplace in existence, and is filled with (3) *"a deep, strong, quiet sense of awe and wonder."* Thus, Rabindranath Tagore, the Indian poet (born 1861), declares:

> At the immortal touch of thy hands my little heart loses its limits in joy and gives birth to utterance ineffable. . . . All that is harsh and dissonant in my life melts into one sweet harmony — and my adoration spreads wings like a glad bird on its flight across the sea. Drunk with the joy of singing I forget myself and call thee friend who art my lord. . . . He it is, the innermost one, who awakens my being with his deep hidden touches. He it is who puts his enchantment upon these eyes and joyfully plays on the chords of my heart in varied cadence of pleasure and pain. Days come and ages pass, and it is ever he who moves my heart in many a name, in many a guise, in many a rapture of joy and of sorrow.[6]

[5] *Elements of the Science of Religion,* New York, Scribner, 1899, Vol. II, pp. 198–199.

[6] Tagore, Rabindranath, *Gitanjali* (Song Offerings), pp. 67–68; Copyright 1928 by The Macmillan Company. Reprinted by permission.

What the mystic carries away from his experience as uppermost is an abiding impression of holy awe, overwhelming veneration, ecstatic love of God. When the climax has passed, he declares that (4) *his experience is ineffable.* The words he may use to describe it are, he believes, symbolic, opaque, utterly inadequate to express reality. That he has apprehended God face to face he does not doubt. Thus Tagore says: " I boasted among men that I had known you. They see your pictures in all works of mine. They come and ask me ' Who is he? ' I know not how to answer them. I say, ' Indeed, I cannot tell.' They blame me and they go away in scorn. And you sit there smiling." [7]

The mystic's experience has for him a profoundly convincing power. It is supposed to contain (5) *an authoritative revelation of divine truth* which satisfactorily solves his religious problems. He attains in his supreme moment what others may pursue for a lifetime without attaining. In consequence, the mystic feels completely at home in the universe and is confident that his destiny is happy and secure. Thus, St. John of the Cross declares, " And the moment such a soul places itself in the presence of God it makes an act of knowledge confused, loving, peaceful, and tranquil wherein it drinks in wisdom, love, and sweetness." [8]

In the demand for a satisfying insight into reality the mystic and the rationalist are one, however different their methods of realizing that demand. (6) *The method of the mystic is concentration or contemplation.* He deliberately practises more or less elaborate exercises to prepare himself for the ecstatic climaxes of experience. The mystic returns to the ordinary ways of living with a purpose to consolidate and to communicate the treasures he has discovered. His method is complementary rather than antithetical to the critical procedure of reason.

Few, indeed, claim to know with such intuitive certainty as the higher mystic. Fewer still are able to tell distinctly what they know. These facts account for the widespread, but futile, denial of the reality of the mystical experiences. The theologian finds in them some of his most important and precious materials. W. R. Inge (English, born 1860) declares that this " dim consciousness of the *beyond,* which is part of our nature as human beings, is the raw material of all religion, and perhaps of all philosophy and art as well." [9]

The six marks of mysticism specified in the preceding paragraphs seemingly apply to the extreme forms of mysticism of every creed, clime, or epoch. These marks supply the criteria for recognizing milder or less

[7] *Op. cit.*, p. 93. Reprinted by permission.

[8] Quoted by Bennett, C. A., *A Philosophical Study of Mysticism,* New Haven, Yale University Press, 1923, p. 71.

[9] Inge, W. B., *Christian Mysticism,* New York, Scribner, 1899, p. 5.

ecstatic varieties. It is probable that a mystical element exists in all religion, and that every religious person has had at different times experiences which are essentially mystical. Examples of mystical rapture and exaltation occur sometimes in social forms of religion, as well as in esthetic and even scientific activities.

Let us note some simple examples of mild mystical experiences which have a religious quality. The child's awakening to a consciousness that nature is somehow alive and that he is not alone in the world is a mystical revelation. It is akin to the poet's communion with nature, or to the prophet's thrilling discovery of a higher form of righteousness. The youth who discovers an occupation which he calls his " mission in the world " and who falls in love with a lass who is " destined to be his own " experiences a kind of mystical ecstasy. The mystical tone of calmness and awe may be felt, too, during and after contemplative prayer or satisfying worship. A mystical experience of another kind is that of the mother who suddenly realizes the divine gift embodied in her young child.

H. G. Wells has given us an eloquent account of occasional mystical experiences which he has:

> At times, in the silence of the night and in rare lonely moments, I come upon a sort of communion of myself and something great that is not myself. It is perhaps poverty of mind [or] language obliges me to say that this universal scheme takes on the effect of a sympathetic person — and my communion a quality of fearless worship. These moments happen, and they are the supreme fact of my religious life to me; they are the crown of my religious experience.[10]

No affective experience, as such, is uniquely or distinctively religious. In other words, every human emotion and sentiment may become suffused with religious significance; and, conversely, every feeling which appears in religion also appears in other phases of life. All our experiences involve emotion in the sense of a sustaining interest or desire. Emotion is our human way of evaluating or appreciating things. Religious feelings are distinguished from others by the object or idea which directs and ennobles them; namely, the idea of God. The conception of God, however, which the mystic builds reflects the traditions and community of thought in which he has been trained. Religion is our personal, evaluating reaction to our whole conception of life.

(*c*) Practical Religion.—A third type of religious attitude which has been prevalent in the last generation has been called " the gospel of action." Devotees of this cult are not much concerned with theoretical

10 Wells, H. G., *First and Last Things,* London, Constable, 1908, p. 60; quoted with permission of Mr. Wells.

questions about the meaning or rationality of the universe. They are not given to transports of piety or mystical exaltation. " A sedentary life," says Nietzsche " is the real sin against the Holy Spirit. Only those thoughts that come by walking have any value." These practical men may be enthusiastically concerned, however, with social morality, with the creation of a more perfect state in which justice shall rule. They are essentially actors, social servants, promoters of righteousness.

They find the essence of religion in a moral code which satisfies their sense of perfection. Some of them indirectly venerate a God whom they tacitly assume as the author of the ethical values they esteem. Such a moralistic religion is well represented by the creed of a midwestern manufacturer who called himself an atheist; during his lifetime he had inscribed on a great tombstone the epitaph, " This world is my home; to do good is my religion." At the other extreme stand the great prophets, such as Moses, Isaiah, and Jesus, who demand, in the name of Jehovah, a higher and happier righteousness.

One who defines religion from this point of view will not emphasize reason or feeling, although he may not deny the value of either. William James offers a transitional point of view between the two previous types of definition: " In the broadest and most general terms possible religion consists of the belief that there is an unseen order, and that our supreme good lies in harmoniously adjusting ourselves thereto. This belief and this adjustment are the religious attitude in the soul." [11] The notion of belief here represents the rational, but not too rational, elements in his definition. The new factor is adjustment. This was not specifically mentioned in previous definitions.

F. H. Bradley (1846–1924), the distinguished English metaphysician, goes farther still: " We have found that the essence of religion is not knowledge. And this certainly does not mean that its essence consists barely in feeling. Religion is rather the attempt to express the complete reality of goodness through every aspect of our being." [12] Another splendid definition in this class is that of George A. Gordon: " Duty seen in the light of God's eyes, beheld in the fire of God's presence — that is religion in its aboriginal sovereignty, awe, beauty, and power." [13] It was the incomparable master of ethics, Immanuel Kant (German, 1724–1804) who first made moral reason autonomous and normative in religious belief. He declares, in his *Religion Within the Limits of Pure Reason:* " Religion is (subjectively considered) the recognition of all our duties as divine commands."

[11] James, William, *The Varieties of Religious Experience,* New York, Longmans, Green, 1914, p. 53; quoted with permission of publishers.

[12] *Appearance and Reality,* p. 453; copyright 1902 by the Macmillan Company. Reprinted by permission.

[13] Sermon, March 14, 1914.

(*d*) Summary Characterization of Religion. — Each of the above types of definition enlarges our conception of religion. They are partial rather than mistaken, complementary rather than contradictory. They warn us against hastily adopting too narrow a definition as final and authoritative. They teach us that religion is to be understood in terms of human needs and desires. They suggest the ramifying forms that man's religious interests may assume. Now one phase of religion may predominate and now another, according to the peculiarities of individual temperament or social tradition.

Thus, reason may save the mystic from vagaries and self-gratification; it may save the practical man from fanaticism and lost causes; it gives to religion breadth and balance. Emotion saves the thinker from cold abstractions and formalism, and fills the moral man with enthusiasm; it gives to religion richness and warmth. But these and all other phases of religion must ultimately justify themselves in the fruits of action, in the works of righteousness.

The preceding definitions indicate how much must be included in an adequate definition of religion. Such a definition will involve at least (1) a belief in a superhuman power who controls our environment; (2) a conscious endeavor to enter into friendly relations with that power for the purpose of conserving and increasing individual and social values; and (3) an appreciation or enjoyment of the "peace of God that passeth all understanding." These three factors constitute the inner or subjective side of religion. Religious dispositions have multifarious expressions in acts, institutions, rites, worship, and so forth. We must conclude that *all phases of man's personality share and blend in the religious consciousness.* As soon as any end whatever is related to God it gains religious significance. It has been said that nothing is religious until one gets the experience of God and after that everything is.

The two following definitions of religion are attempts to epitomize the several phases of religion. Galloway suggests tentatively that religion is "Man's faith in a power beyond himself whereby he seeks to satisfy emotional needs and gain stability of life, and which he expresses in acts of worship and service."[14] H. F. Amiel (Swiss, 1821–1881) says: "Religion is not a method, it is a life, a higher spiritual life, mystical in root and practical in its fruits; a communion with God, a calm and deep enthusiasm, a love which radiates, a force which acts, a happiness which overflows." *Religion, in short, is man's search for a more secure and abundant life in a precarious world in which God is the greatest fact.*

[14] Galloway, *op. cit.*, p. 184.

2. Methods of Studying Religion

(*a*) Psychological Methods. — Our survey of representative definitions of religion has brought before us some of the major problems which confront a student of religion. His data are multitudinous, complex, and often obscure. The remainder of this chapter will be devoted to setting forth the most promising methods of investigating the problems of religion. We assume that only gain can come from knowing the fullest possible truth about religion. Nothing in religion is to be feared more than error save the pernicious fancy that error itself is an illusion. The study of religion must follow sound methods which are in harmony with the general methodological principles of science and of philosophy. Without this procedure, it cannot win a rightful place among the great branches of human knowledge.

Three major methods of studying religion are now generally recognized: the psychological, historical-comparative, and philosophic methods. These methods seek to answer respectively three basic questions which may be asked about any religious experience or institution: What is it? How has it come to be what it is? What is its worth? In short, description, genesis, and interpretation are the three methods of understanding religion. It is assumed that the general methods of science (accurate observation, verification, and so forth,) apply in all scientific studies of religion.[15]

(1) *Psychological Problems in Religion.* — In a strikingly simple way, J. B. Pratt has stated, in the Preface to his book, *The Religious Consciousness,* the aim of the psychology of religion. He says:

> The science, if such we may call it, is still young, and good books upon it are scarce. [He then states the purpose of his book:] It is to *describe the religious consciousness,* and to do so without having any point of view: — without, that is, having any point of view save that of the unprejudiced observer who has no thesis to prove. My aim, in short, has been purely descriptive, and my method purely empirical. . . . I hope at least that I have avoided provincialism, both of the geographical and of the intellectual variety. In order not to be confined to the American Protestant point of view I have seen what I could of Roman Catholicism in Europe, and of Hinduism and Buddhism in India, Burma, and Ceylon.[16]

The subject-matter of the psychology of religion is the totality of the religious experiences of human beings. We have not space to enumerate the multitudinous sources from which the psychologist gathers his materials. Having obtained his data, he proceeds to analyze, compare, and

[15] *Cf.* Macintosh, D. C., *Theology as an Empirical Science,* New York, Macmillan, 1919, especially pp. 26–46.

[16] Copyright 1920 by the Macmillan Company. Reprinted by permission.

correlate them. He is especially interested in discovering the general conditions and consequences of religious experiences. He endeavors to link religious phenomena with familiar beliefs and practices, and with the general laws of psychology. The main problems which the psychologists have studied are conversion, revivals, mysticism, prayer, worship, ceremonials, magic, inspiration, sacrifice, and childhood religion.

(2) *Conversion.* — Psychologists have made in recent years extensive investigations of conversion in its manifold varieties. Conversion is perhaps the most important and vivid crisis which often occurs in religious life. It is by no means so extensive as religion itself; again it is sometimes without religious significance. The term may be extended to apply to any sudden and seemingly unaccountable awakening of personal power or intellectual insight. The division of religious conversions into gradual and sudden types is rough and inexact but convenient to follow.

In gradual conversion, the individual slowly grows into a religious consciousness and a more or less unified moral personality. This process is especially characteristic of adolescence. " The great task of the adolescent," says Pratt, " is to grow out of thinghood into selfhood." [16] It generally involves a change from a naturalistic to an ethical attitude toward life, a transformation of man the animal into man the spirit. This transformation has been called " second birth," after the profound saying of Jesus, " Ye must be born again."

Our account of sudden conversion must be summary. For those persons who have undergone no normal religious development, conversion marks the conscious beginning of a larger life. It is a leap forward in the process of self-making, and may amount to a mental cataclysm. In the preparatory stage the individual finds himself wrestling unsuccessfully with problems of mental adjustment. He feels out of harmony with the physical, social, and ethical forces which play upon him. He can find no principle powerful enough to unify his conflicting instincts and wavering purposes. If he thinks of the ultimate power as God, then he feels himself at variance with God's will. He suffers from discontent and anxiety, from stress, strain, and confusion, and sometimes from a sense of sinfulness and worthlessness. In spite of his most earnest efforts, he fails to find his way out of this distressing state of mind. He faces defeat in his wrestle with fate.

The intense climacteric stage brings to the restless and depressed individual a profound change in his deepest self. He experiences an abrupt and unaccountable influx of insight and power which is not the result of growth or his personal efforts. He awakens to, and gets firm hold of, an idea which quickly sets his chaotic life in order. This idea is a purpose, or group of purposes, of which he may have thought before but which now advances to

become the organizing center of his new life. The individual yields himself to the incoming energy or ideal, and resolves to live in harmony with the ultimate power which seems to give and sanction it. His feeling of depression is supplanted by elation. His sense of estrangement from God passes away. Joy, peace, and assurance come to reign in his soul. A new moral self, unified and victorious, has been born.

The chief result of conversion is that *revaluation of life which is characteristic of religious experience.* Whatever its emotional by-products, rebirth is the culmination of a process which involves much strenuous thinking. At the same time that the convert comes to himself and to appreciate new values, the world, too, changes its appearance and acquires a larger significance and intimacy. He comes into control of surprisingly new psychic forces, and can achieve ends which before were impossible. He is often able to break with habits and modes of living which he has come to condemn. He becomes " a changed man," a new and more unified self.

The book of A. C. Underwood called *Conversion: Christian and Non-Christian* is " a comparative and psychological study " of conversions in all of the principal religions of the world. In his concluding chapter he declares: " Ample evidence has now been produced to show that conversion is a permanent possibility of man's nature as man, and that it may, therefore, occur in any religion." Then he endeavors to frame a definition of conversion which will cover all cases; it is " a reaction taking the form of a psychological surrender to an ideal, and issuing in moral development." [16a]

(*b*) Historical and Comparative Methods in Religion. — (1) *Historical and Social Studies of Religion.* — The scientific student of religion is not satisfied with merely a psychological description of a person or institution. He wants also to know its *origin and evolution, and its variations in different societies.* The experience of Christians is not adequately explained apart from Jesus, and Jesus was too much of a Jew to be accounted for apart from the Hebrew prophets. But the prophets also had a history, and prophecy appears in different forms in the ethnic religions. In short, we need the richness and the breadth of understanding which come from the historical and comparative study of religion.

We assume that the methods of the historian are familiar. The historian of religion has innumerable but perplexing data. The most important of these, perhaps, are the literary remains of the religious leaders of the past. Religious writings which have been treasured through the centuries by a community of believers are called scriptures, bibles, or sacred books. The Vedas, the Christian Bible, and the Koran are notable examples of the relatively few sacred books which exist. The study of the structure, history, and original meaning of these and other documents is of fundamental im-

portance in the history of religions. This study goes by the unfortunate name of *higher criticism. Its simple purpose is to ascertain all the truth possible about the meaning and the author of a literary work.*

The historian assumes that religion has had a natural growth like other aspects of human culture. *He seeks to trace the origin, development, and differentiation of religious beliefs, practices, and communities.* The application of the *method of evolution* to religion has tremendously increased our understanding of it. This postulate of direction or development in religion is made as any fruitful assumption in science is made, to be used as a tool of investigation.

The contemporary historian assumes that religious conceptions and customs are deeply rooted in the social life in which they originate. He wants, therefore, to know the *totality of social causes* which have produced whatever doctrine or institution he is investigating. He traces so far as possible the geographical, economic, political, and cultural influences which have affected it.

Each of the classical theories of the atonement, for example, reflects the dominating social pattern or setting of the community in which it emerged.[17] Thus the *sacrificial theory* appears in the New Testament because Christianity arose in a Jewish society in which the offering of sacrifices to expiate sins was an intrenched custom. In the early middle ages, when all life was organized with reference to the feudal scheme, it was thought to be wrong to forgive until the injury to one's honor had been satisfied. St. Anselm's *infinite-honor theory* developed under the influence of this social morality. When disobedient men offended the infinite honor of God, God could not honorably or justly forgive them without the infinite satisfaction offered by the sufferings of Jesus. Then absolute monarchies became the fashion in Europe, and it was thought that all violators of the king's will had to be punished. Then Jesus' death was regarded as the means of satisfying the *punitive justice* of God. When an industrial democracy developed the pattern and institutions of property, the crucifixion of Jesus was interpreted as *paying the debt* which sinners owed to God. This view finds expression in the hymn containing the lines: " Jesus paid it all; all to Him I owe."

Thus in each stage of social evolution God is conceived as forgiving in accordance with the approved ideals of the community. Undoubtedly, another theory is now developing under the influence of the moral conceptions of our age. The clear-cut analogies of statecraft have been widely influential in shaping man's religious views of life. The search for social causes, which we have just illustrated, is the central idea in the sociological

[17] *Cf.* Robinson, D. S., *The God of the Liberal Christian,* New York, Appleton, 1926, pp. 35-37.

study of religion and in the so-called social theology of our time. It is important to note that while the historian tells us how religious conceptions have developed, he does not tell us which ones are best.

It is natural that in any stage of evolution beliefs and practices should survive which were characteristic of an earlier age. These survivals suffer a variety of fates. They may lose their religious significance altogether. Thus, the mascot of the baseball club and the throwing of rice at weddings are vestiges of religious customs practised by our remote ancestors. Sometimes the old is transformed and assimilated into the new, as the Saturnalian festival is preserved in our Christmas celebration. The search for the left-overs of an earlier epoch — *the method of survivals* — is a useful corollary of the method of evolution. It is worthy of note that the theologian is no more responsible for outgrown beliefs than is the scientist for discarded hypotheses.

(2) *The Bible and the Prophets.* — An immense amount of historical research has been bestowed upon the bibles of mankind. The painstaking scholars of Christianity have traced the evolution of the Christian Bible and interpreted it in the light of the most varied historical information. In consequence, we of the twentieth century are the first in the history of the church who can arrange the Biblical writings in approximately chronological order. This achievement has cost an amount of intellectual travail which is comparable to the history of the heliocentric theory of the solar system. It means that we can now trace the great conceptions of the Bible through the stages of their long development.

One of the greatest accomplishments in the historical study of the Bible is the proof that the prophetic Amos and not the priestly Genesis is the oldest book of the Bible. The leading prophets come before the main body of the law and the wisdom literature. In other words, the prophets and not the priests were the reforming forces in the development of the religion of Israel.

By reference to prophecy we may briefly indicate how all methods of studying religion may be brought to play upon a single problem. (*a*) First of all, the *historian* applies the method of higher criticism to the interpretation of prophetic literature. Then he strives to trace the steps, conditions, and results of the development of prophecy from its beginning. (*b*) The *psychologist* inquires concerning the nature of prophetic consciousness and leadership. He is interested especially in ascertaining how the prophet obtains his divine message. He may compare the rational methods of the true prophet with the trances, casting of lots, and other pathological and mechanical methods of the diviner, *shaman,* and false prophet. (*c*) The *comparative historian* will make extensive comparisons of the prophets of one religion with those of other religions and other epochs. (*d*) Finally, the

philosopher will seek to determine the human value of the prophetic consciousness and of the ethical deliverances of the prophets. He might find, for example, that the chief contribution of the Hebrew prophets was a higher moral conception of God.

(3) *The Comparative Method.* — The comparative method is a phase of historical inquiry taken in the broadest sense. S. A. Cook says, "*The comparative method is the unbiased coördination of all comparable data irrespective of context or age.*" [18] It is a search for likenesses and differences in phenomena of widely different individuals or groups. The problem investigated may be the idea of God, ceremonials, sacrifice, the details and colors of vestments, or the worship of mice. Whatever the problem, the essence of the method remains. The comparative historian is especially interested in coördinating aspects of highly developed religions with corresponding aspects of primitive religions. He draws many of his materials from anthropology.

If the comparative historian were interested, for example, in the remarkable narratives in the Book of Genesis, he might search for parallels in other religious literatures. To execute such a task is exceedingly laborious. The painstaking study of the Assyrian cuneiform writings has brought to light many interesting parallels to the stories and teachings of Genesis. For example, these writings contain a dramatic account of creation which resembles the Biblical accounts in important respects. In both cases, the world arises from a vast waste or chaos; and in both the heavenly bodies are created first, then plants and animals, and lastly man. Two tablets have been found recently which contain an account of the fall of man in the Garden of Eden.[19] These prove either that the story in Genesis was borrowed from the Babylonians or that both accounts had a common source. Pfleiderer points out that "in the Persian religion there are found teachings of the kingdom of God, of the good spirits who surround the throne of God, of the spirit hostile to God, and of an army of his demons, of the judgment of each soul after death, of a heaven with eternal light, and of the dark abyss of hell." [20]

It is also very probable that the Biblical narrative of the deluge (*Genesis* vi–ix) came through some channel or other from the Babylonian stories of the flood. While George Smith was working in 1872 on some clay tablets from the library of Ashurbanipal, he discovered the first deluge tablet. It dates from some time before 2000 B.C., and is, therefore, at least

[18] *Encyclopaedia of Religion and Ethics* (Hastings, editor), New York, Scribner, 1919, Vol. X, p. 664.

[19] See Chiera, E., *The Outlook,* January 3, 1923.

[20] *Congress of Arts and Science,* Boston, Houghton, Mifflin, 1905, Vol. I, pp. 267–268.

1200 years older than the oldest documents of Genesis. It is the eleventh of twelve tablets which contain the twelve cantos of the great epic which relates the adventures of King Gilgamesh in his efforts to obtain eternal life.

Gilgamesh was divinely forewarned of a mighty rainstorm. He was commanded to build a ship and to " bring living seed of every kind into the ship." The storm swept over the earth at the appointed time, and raged until all visible land was overwhelmed. Finally calm came upon the sea, and a great silence. After nineteen days Gilgamesh sent forth a dove which soon returned. Later he sent forth a raven which did not come back. Then he " sent everything forth to the four quarters of heaven, and offered sacrifice upon the mountain peak." [21]

The study of comparative religion is a powerful antidote to all forms of provincialism. One who is acquainted with this subject can no longer regard other religions as absolutely false in contrast to the unquestionable truth of his own. He learns to discern beneath the husks of alien legend and symbolism many precious kernels of religious sentiment and truth. The American theologian, Shailer Mathews, declares: " One could hardly feel that a truth which appeared in Christianity was any the less true when it appeared in Buddhism; or that the desire for forgiveness was any the less sincere in the penitential songs of the Babylonians, than in the psalms of David." [22]

The student of comparative religion no longer requires or expects religious experience to conform to a single pattern, nor religious theories to be expressed in a single set of images. He knows that there are many ways to God. He is prepared also to recognize outgrown dogmas and patterns of thought in his own religion. He has no interest, however, in condemning or ridiculing the useless or curious things he discovers. He is ever in sympathetic search for the deep human needs and longings which have produced and preserved the diverse religious phenomena which he studies. The success of this search requires the support and complement of psychological analysis as described above. The comparative study of religion thus puts an end to the isolation of religious groups. It teaches us that we cannot know the truth of our own religion without knowing something about other religions. But questions of validity in religion require the strenuous methods of philosophy yet to be explained.

(*c*) Philosophical Method in Religion. — The philosophy of religion is the focus or culmination of all other studies of religion. It assumes

[21] Rogers, R. W., *Cuneiform Parallels to the Old Testament,* New York, Eaton and Mains, 1912, pp. 90–98.

[22] Mathews, S. (editor), *Contributions of Science to Religion,* New York, Appleton, 1917, pp. 381–382; quoted with permission of publishers.

the data and results of every other method, and is an *attempt to coördinate and to interpret* those results. A leading American theologian has said: "Philosophy has the right to criticize any dogmatic platform, to examine it from the standpoint of reason. It acts as a purifier, corrective, and ennobler. The last word is said by the philosopher." [23]

The purpose of the philosophical study of religion is to determine the value and the validity of religion by an impartial, comprehensive, and critical study of religion in all of its principal aspects. The philosopher gathers his materials from all quarters and from all stages of religious evolution. Like all other students of religion, he makes extensive use of the observed facts of religious experience. F. H. Bradley declares — and few philosophers have employed more pulverizing engines of skeptical criticism than he — "The man who demands a reality more solid than that of the religious consciousness, seeks he does not know what." [24]

The nature of religious value is the distinctive problem of religious philosophy. The reason is that religion is a great discoverer, conserver, and transformer of human values. But the criticism of values is peculiarly a philosophical problem which lies beyond the province of every special science. Let us note briefly how the scientific methods of studying religion considered above lead up to questions of value which they themselves do not answer.

The *psychologist* seeks to describe the sensations, emotions, behavior, and so on, which appear in any spiritual exercise, whether a sacrifice or a dance, prophetic inspiration or mystical ecstasy. But we must also ask, declares Coe, "what the devotee is after, whether he gets what he is after, and how this particular good is related to other goods in the total self-realizing life of man. This phase of religious life is objectively present no less truly than the parts into which we resolve mental complexes." [25]

In a similar way the *historian* of religion inevitably raises questions of worth. He may tell us that prophets founded the Jewish and Christian religions and that priests have helped to preserve them. The philosophical theologian goes on to inquire what significant functions prophets and priests fulfil in religion and society. Are their moral teachings in harmony with the best ethical thought? Do the historical institutions of religion meet the moral, esthetic, and intellectual needs of men in the most perfect way possible? Can one find running through all the theories of the atonement

[23] Foster, G. B., *Christianity in its Modern Expression,* p. 3; copyright 1921 by the Macmillan Company. Reprinted by permission.

[24] *Appearance and Reality* (ed. 2), p. 449; copyright 1902 by the Macmillan Company. Reprinted by permission.

[25] Coe, G. A., *The Psychology of Religion,* University of Chicago Press, 1916, p. 11; quoted with permission of publishers.

a single basic principle? Perhaps, for example, they are all endeavors to explain how we may win harmony with God in a way that is consistent with the highest moral demands of the time.

Again, *comparative religion* is productive of questions of value. For example, is the Babylonian or the Biblical account of creation superior religiously? The Babylonian account is pantheistic; the gods and everything else originate in a primordial chaos which somehow begets itself. In the Biblical account God himself, the unique Creator, the eternal "I AM," stands before all else, and his first act is to create light. The narrative definitely protests against any sort of pantheism. Further, the Babylonian account of creation presupposes a radical dualism; deity creates nature only by dint of tremendous exertion in a dreadful combat with opposing forces. In the Biblical account there is no such antithesis: God creates the world without struggle, by the mere word of His command.

These examples are sufficient to show how other phases of theological study issue in difficult questions which the philosopher strives to answer as best he can. First of all, What is religious value? and, How is it related to other types of value? Since the self (often called the soul in theology) is the source and appreciator of all values, it is important to know the nature of the self. The search for the meaning of the self leads to this question: In what kind of society would religious and other human goods thrive best? It leads also to the question of human destiny or immortality. None of these problems can be answered apart from a conception of God and of His relation to man and the world. Religious values grow out of faith in a God who is believed to be real, and would largely disappear with the loss of this belief. How is God related to the realm of nature? Is He identical with nature (pantheism), independent and co-eternal (dualism), or is nature utterly dependent upon His unceasing dynamic power (theism)? A religious view is an answer to the question, How must the world be judged if the highest good is to be real?

The fundamental problem, then, in the philosophy of religion concerns the existence and nature of God. The critical method of philosophy, described in the following chapter, is employed in solving this and other philosophical problems of religion. In conclusion we shall only suggest some of the directions in which we may look for indications of the character of God.

First of all, if true knowledge of nature exists, if somehow the thoughts of a race of men can repeat the order of the cosmos, does this fact require a unitary and intelligent world-ground? Can the measure of order which science has discovered in natural phenomena be explained apart from a supreme intelligence? The philosopher will also consider the fact that the world seems constituted in such a way as to make possible an ever-

increasing abundance of varied values (notably truth, goodness, and beauty). What bearing does this fact have upon the nature of God? On the other hand, what explanation can be given of the physical, moral, and other evils which exist in the world? In one of the finest discussions of evil that has been written, G. A. Wilson declares, "The problem of evil may still remain a problem without shattering our belief, because after the worst is said, life normally proves abundantly worth living." [26]

The general ground, then, for believing in the existence of God must be found in the necessity of accounting for our experience. Since our experience admittedly is not entirely under our control, we are obliged to assume the existence of a source of that control which is adequate to explain the variety, order, and value which human experience reveals. God, perhaps, is found wherever He acts; He seems to act wherever we go. Thus, the philosophy of religion leads us to some kind of life-view and world-view. "Theology," declares Knudson, "even in its empirical form is at heart metaphysical and always will remain such." [27] In its basic problems it merges with metaphysics, which seeks, from a somewhat different point of view, precisely the same end.

3. What is Theology?

A comprehensive term is needed to designate all scientific and philosophical studies of religion. *Theology* is well fitted for this purpose by etymology (doctrine of God), but its general sense is easily confused with two other meanings. Most commonly it refers to the organized system of doctrines held by some historical religious community. In this *dogmatic* sense we speak, for example, of Calvinistic, Unitarian, or Mohammedan theology. Again, theology is sometimes identified with the philosophy of religion. From this point of view it may be defined as *a reasoned and systematic interpretation of religion and of its place in our total life and world.* This *philosophical* meaning is preferred in the more progressive circles of thought. The distinction between theology and the philosophy of religion is growing less and less. In some contexts it is convenient to broaden theology to include every unprejudiced study of religion. From this *general* point of view, theology is made up of the three following grand divisions (in reverse order of age):

Psychology of religion = empirical theology.
History of religion = historical theology.
Philosophy of religion = systematic theology.

[26] Wilson, G. A., *The Self and Its World,* p. 249; copyright 1926 by the Macmillan Company. Reprinted by permission.

[27] Knudson, A. C., *Present Tendencies in Religious Thought,* New York, Abingdon Press, 1924, p. 146.

The older theologies were largely dogmatic in the sense of being based upon some authority other than reasoned knowledge. The traditionalistic theologian posited a sacred book, inspired church, or divinely appointed prophet, whose teachings were final, and the validity of which he did not question. The Bible of the Protestant, papal pronouncements for Roman Catholics, and the Church in Eastern or Greek orthodoxy are examples of such authority. The task of the dogmatic theologian, then, was to elucidate his accepted body of doctrines and to organize them into an harmonious system. Deduction was his method of procedure. He regarded as true any doctrine which logically followed from or agreed with his assumptions.

The dogmatic method, however, inevitably develops insoluble problems. Religion, as we have seen, is life with God — thought as well as deed. For this reason no set of religious beliefs can be isolated from current morality, social patterns, or scientific generalizations. In an ever-changing civilization, fixed dogmas and modes of thought are constantly in danger of becoming either inconsistent or inconsequential. For example, since the days of Copernicus, we can no longer think of heaven and hell as places above and below us. Again, in a democratic civilization it hardly seems fitting to represent a spiritual brotherhood as a kingdom; "democracy of God" or "beloved community" appear to be far more appropriate terms. For reasons of this kind, apparent conflicts arise between religion and science, which, as a matter of fact, are often conflicts between old and new science.

To solve the conflict between tradition and new knowledge some unprogressive but inventive theologians have tried allegorical interpretation, the separation of revealed from natural theology, or the partition of life into sacred and secular. These and other compromises now seem scarcely more than makeshifts. The whole trend of contemporary theology is to bring religion out of isolation and to connect it with our total life.

More and more it has been discovered that the traditional elements cannot be authoritative in a living religion, and that the teachings of science and philosophy of the day largely determine what we think in theology. Progressive theologians accept uncritically no authoritative body of doctrines. They are like other scientists in that their only assumptions are methodological; namely, whatever rules and postulates they find necessary to develop their science. Shailer Mathews recently asserted that, "Religious thought is not nearly so anachronistic as those who know nothing about it appear to suppose. . . . [It] can hardly be expected to reshape itself at the behest of every man who has his particular theory to champion." [28] Some of the old prejudice against dogmatic theology survives to

[28] Mathews, *op. cit.*, pp. 370–371; quoted with permission of Appleton and Co.

be misdirected against the sincere and praiseworthy efforts of the progressive theologian.

The task of theology at the present time is to construct a theory of religion which shall be at once significant and satisfying in life and harmonious with the best knowledge of contemporary civilization. Each generation must build its own theology, its own philosophy of religion, if it is to do its own thinking. This difficult task, however, is a great responsibility, and many men are neither fitted nor willing to assume it. Before discussing philosophic method in religion, we shall note one important contribution of dogmatic theology which is often overlooked.

A great dogmatic system rests upon a kind of implicit, although inadequate, inductive logic. Whatever doctrines are accepted as authoritative rest ultimately upon the religious experiences of individual prophets, teachers, or wise men. But if a prophet, as the traditionalist supposes, has proved his preëminence by winning a long line of disciples and satisfying their needs, he has earned the right to speak with the authority of an expert. Hence, the traditionalist practises the worthy virtue of respecting recognized greatness in religion. In addition, he saves himself from troublous doubts and questionings for which perhaps he could find no better answers than tradition offers. As a matter of fact, he gains recognition in the religious community which the founder established, and this is of greater value to him than the somewhat negative virtue of perfect scientific method. The venturesome student easily underestimates the arduous prerequisites of a genuine expert in religion. To speak the words that multitudes will heed and feed upon demands a truly great and costly wisdom.

The traditionalist's esteem for the great prophets who made his religion induces him intensively to study their lives and teachings. A systematic study of the work of Gautama, Jesus, Paul, Mohammed, Luther, and other creators of religion, is intrinsically valuable. This case method is an essential part of inductive procedure. If only the dogmatic theologian would surrender the assumption that the founder of his religion alone had religious truth, he would be near that impartial psychological and historical investigation which is a chief part of scientific theology. He might then pass from the authority of a teacher or a community to the authority of the fullest tested truth which the unprejudiced thought of his time could furnish.

The difficulties of theological science evidently are extraordinarily great. They are due (*a*) to the vast range, complexity, and obscurity of its data; (*b*) to the prejudices, dogmas, and vested institutions which it encounters; and (*c*) to the profound metaphysical problems it must face. Few aspects of human experience are so distorted by superstition or so narrowly and persistently misinterpreted as the religious. This great

variety of complications promises no adequate solution now or in the future unless a few men here and there are able to look at the problems coolly, scientifically, philosophically, and with no motive save to know the fullest possible truth about religion. Albert Schweitzer has well suggested that there are four conditions for a deep theology: religious feeling, historical insight, critical acumen, and philosophical reflection.

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CHAPTER XX

METAPHYSICS

1. Philosophic Problems

Philosophy exists indigenously in every community, though its name and garb be strange. It is as natural and inevitable to man as politics, poetry, and religion, for man, *homo sapiens,* perennially asks about the what, why, and whither of his life and world. The wonders and crises of man's existence, his aspirations, sufferings, and achievements, provide philosophical questionings. Through hard original reflection he may distil some answers from his own experience. Most of the scraps of philosophical insight which he possesses he picks up piecemeal from diverse traditions: superstitions, dogmas, doubts, hypotheses, which, because of their seeming significance or literary charm, have survived the wreckage of the centuries. Just as barbarous and scientific medical practices exist side by side in the same community, primitive philosophical beliefs, often baseless or long refuted, may live even in the minds of the most learned.

The unrecognized purveyors of philosophical wisdom and foolishness are a motley crowd: medicine men, alchemists, and magi, poets, humorists, and tragedians, prophets, sages, and savants. Such men sometimes pronounce judgments which suggest the shoreline of a vast sea of verity which is dimly sensed as having momentous significance for human destiny if only its fuller bearings could be clearly fathomed. Who could not find pronouncements like the following among the opinion he cherishes: fate is cruel and inexorable; the universe is a vast machine; all things work together for good; the world is going to the devil; men are created free and equal; the soul is an immaterial substance; the exception proves the rule; a lie is never justified; there is no disputing about tastes? All of these are philosophical propositions, and all of them are open to question. If they are well-founded, a critical mind wants to know the reasons which support them. He will supplant as far as possible the cryptic intuitions of the seer with a self-conscious and cogent argument.

Evidently there is need for a critical and assiduous study of the meaning of life and of the world. *Philosophy is a critical and thorough-going interpretation of reals and ideals and of man's fortune as wrapped up in them.* "Philosophy," declares Leighton, "seeks a totality and harmony of reasoned insight into the nature and meaning of all the principal aspects

of reality. A complete philosophy includes a *world-view* or reasoned conception of the whole cosmos, and a *life-view* or doctrine of the values, meanings, and purposes of human life."[1] To set forth some of the problems and methods of philosophical study is the purpose of this chapter.

The first men in the Occident to make it their business to investigate such profound problems lived in Greece in the sixth century before Christ. They were learned in the culture of their day and sought a deeper understanding of the world and of human existence. For this reason they were called wise men or philosophers, for *philosopher* means, etymologically, lover of wisdom. Aristotle said that for human beings it is appropriate only to seek wisdom because God alone may properly be said to possess it. The wise man is a searcher for the true and the good, for reality and value, the two great centers of philosophical interest. Wisdom is a full and accurate knowledge of facts, a clear and ordered discrimination among values; and the fruit of wisdom is a balanced and rich life lived in the light of that knowledge and discrimination. Wisdom is a blend of that learning and discretion which flow from a comprehensive insight into things as they are and may be.

In this search, the inquirer confronts unusually perplexing problems. He will suffer disappointment if he fails to recognize the limitations of the mind and knowledge of man. Man's deeply prying, world-encompassing imagination poses questions which far outrun his present powers to answer. Some problems admit of definite solutions, while others may only be guessed at. Guessing, however, which grows out of a rich body of experience is a very important form of mental activity. Those stubborn thinkers called philosophers persist in seeking answers concerning ultimate problems even when probabilities, as a rule, are their only reward. Yet their problems are of such paramount importance that bare probability concerning them is often worth more than apodictic certainties about lesser things, such as the origin of a word, the date of a historical event, or the anatomy of a gnat. The nature and well-being of man as affected by the kind of universe in which he lives are the great issues at stake. Since we will have philosophical opinions of some sort anyway, the philosopher believes it is worth while to have the best that a thorough investigation can produce: let a few delve deeply into what concerns all.

2. Types of Metaphysics

The student of philosophy does not go far in his search for the real before he discovers that things often are not what they seem, and that

[1] Leighton, J. A., *The Field of Philosophy* (ed. 2), Columbus, Ohio, Adams, 1919, p. 3.

many mistaken ideals of life are defended, sometimes unto death. What is a real thing? The things which we perceive and know — the only ones we can talk about — seem to be within the field of consciousness and yet to exist outside of the mind. Things also seem to change, and yet how is change possible unless something permanent endures amid the change? And is the world one, two, or many? " How can these things be? "

We have stated three of the basic problems of metaphysics. *Metaphysics deals with the theory of the real as such.* Its aim is set forth with remarkable clearness by Aristotle when he says: " There is a science which investigates being as being and the attributes which belong to this in virtue of its own nature. Now, this is not the same as any of the so-called special sciences; for these others . . . cut off a part of being and investigate the attributes of this part. We are seeking the first principles and the highest causes." [2] In other words, the special sciences answer the question, What does it mean to be, specifically — stones, stars, living organisms, man, and so forth? The answers are the sciences of geology, astronomy, biology, anthropology, and so forth. But metaphysics, according to Aristotle, asks: What are the generic characteristics of all the subject-matters of the sciences? What is the meaning of being or reality itself? We shall sketch, in a brief way, several of the major theories of reality which have been proposed in the past.

(*a*) Naturalism. — The physical world is so bulky and insistent that one easily supposes that an analysis of it will reveal the key to reality. The hypothesis that everything in the world can be explained in terms of *substance,* in the sense of moving particles of matter and their combinations, is the ancient doctrine of materialism. In modern systematic materialism, commonly called naturalism, physical *processes* or mechanical causation are regarded as a sufficient explanation of everything. R. W. Sellars declares, " The basic thesis of all naturalism is that man is a part of nature as an orderly and self-contained spatio-temporal system." [3]

In both forms of materialism an attempt is made to reduce all of the multifarious properties of things — colors, forms, activities, values — to quantities or elements, to atoms or processes. Wishes and purposes, too, are regarded as cogs in a blind and universal machine. The mind and its activities are conceived as forms or effects of body, perhaps as movements of brain atoms or functions of bodily behavior. In short, contemporary naturalism is an attempt to generalize natural science into a metaphysics; it takes as full reality everything which science successfully describes.

Criticism brings to light in naturalism many serious difficulties. Clearly,

[2] Aristotle, *Metaphysics,* Bk. IV, Ch. I.

[3] Sellars, R. W., *The Principles and Problems of Philosophy,* p. 475; copyright 1926 by the Macmillan Company. Reprinted by permission.

it is itself a product of a thinking being, but thinking, as we develop and know it in our experience, is something quite other than cerebral vibrations or whirling corpuscles. Indeed, our ignorance concerning the dark abysses of the brain is colossal. We know thought far better as a unique kind of conscious activity to which physical and chemical properties simply do not apply. We have ideas of round and red objects but no round or red ideas, and no square or upright virtues. And ideas have a way of consciously and significantly referring to other ideas, to present or absent objects, to past and future events. Such symbolic references require a mind to support and interpret them; they are not characteristic of any mechanical processes described by natural science. Matter and energy are abstract ideas, a product of analysis and synthesis. Material and moving things exist, but matter as such does not exist, except as a class concept in the mind of some thinker.

Naturalism does not succeed any better in explaining the evolutionary processes of the universe. The indications of purpose and progress which appear in nature, and the novelties of life and mind which emerge from time to time, fit into none of its categories. But science is committed to a theory of evolution and to the method of experimentation. Both alike presuppose change, duration, direction, and novelty which naturalism cannot provide or explain.

By an exaggerated trust in analysis, the naturalist misses those phases of reality which only synthetic and appreciative insight can reveal. Naturalism as a postulate or method of scientific inquiry is useful and necessary; it is inadequate and inconsistent when advanced as a complete metaphysics, because it fails to make a place for every aspect of reality.

(*b*) Dualism. — Naturalism is usually monistic; that is, it sets up a single principle of explanation (matter or energy). Perhaps two distinct realms exist: matter and mind. This is the contention of those who, like René Descartes (French, 1596–1650) and John Locke (English, 1632–1704), have defended dualism. Each basic kind of substance, they declare, has its own properties and laws. Locke, for instance, argued that material objects possess certain intrinsic " primary qualities " : extension, solidity, motion, and durability. We become aware of these qualities when the objects stimulate our sense organs. But in sensation or perception other " secondary qualities " also appear, such as colors, sounds, and tastes. These do not exist in the objects themselves, but only in the mind when stimulated by external things. Things in themselves are not colored, fragrant, or savory; the real world is a colorless and noiseless realm of substances that are neither cold nor hot. These substances are the abiding substrata or cores of being which support the primary qualities. The mind is a different kind of substance, which knows itself by reflection on its

own operations. Thus, there are two kinds of substances, material and spiritual, known respectively by sensation and reflection, by outer and inner perception. All knowledge is narrowly limited to such ideas, and their combination, as we can obtain by a few rather dull ways of perception. Locke declares: "Whatsoever the mind perceives of itself, or is the immediate object of perception, thought, or understanding, I call *idea*."

The attempt to resolve the sharp dualism of Descartes and Locke has motivated much of modern philosophy. If mind is nothing but consciousness and matter is nothing but extension, how can the two ever be related at all, even in knowing? How can the spatial and the non-spatial meet to influence each other? Yet, somehow, sensations do seem to reflect bodily changes and volitions do appear to effect changes in bodily behavior. Further difficulties in dualism will appear as we study the development of idealism. Dualism is an incomplete attempt to hold to both naturalism and idealism; it is an unstable transition or an incomplete compromise between them.

(*c*) Idealism. — Locke's great *Essay Concerning Human Understanding* (1690) was the first comprehensive theory of knowledge in modern philosophy. He defined many problems of importance. His philosophical successor, George Berkeley, Bishop of Ireland (1684–1753), called in question the substratum of physical things. He frankly and flatly declares that this substratum is a fiction. He seeks to prove by *An Essay Towards a New Theory of Vision* (1709) that all primary qualities are actually in the same position as secondary qualities, for sensations of extension, solidity, etc., come through the senses of touch and vision. Does not a table have as many shapes and sizes as the perspectives from which various observers can view it? Besides, how separate the primary quality of extension from the secondary quality of color? Primary qualities are, in the phrase of Montague, "a geometrical fiction." In short, material substance in the Lockian sense does not exist. It is an artificial abstraction derived by thought from sensation and corresponds to nothing real; there is neither reason nor need for supposing that it exists.

To explain reality we need only suppose, thought Berkeley, that human minds and God exist, and that the former are capable of having ideas. These ideas are imparted to the mind directly by the agency of God without any mediation of material entities or unperceived reals. Intelligent will is the only efficient cause, and "the whole creation is the workmanship of a wise and good agent." The laws of nature express the orderly ways in which God actually affects our minds and communicates with us. To say that things exist in nature means that we have definite and regular perceptions. "To be is to be perceived" by some mind, said Berkeley. Anything

that is not perceived or thought by God or man is simply nothing. " The Universe . . . is a society of spirits with a Supreme Spirit at its head." [4] Berkeley maintained that this simplified conception of the universe leaves out nothing that comes within the wide range of human experience and of scientific description. It realizes *two requirements of an adequate metaphysics: respect for experience and parsimony in explanation.*

This bold metaphysics was perhaps too easily constructed. In particular, the relation between mind and knowledge was too mechanically conceived. Berkeley failed fully to recognize the productive activity of the mind in building ideas; rather he thought of God as producing in us the images of objects. This gap permitted David Hume (English, 1711–1776) to undertake to dismiss soul substance also as a myth and leave only sense impressions and their pale images called ideas. Law or truth for him was merely an habitual association of ideas. When his premises were strictly carried through, knowledge became impossible, and the world was dissolved into a transitory throb of sense.

The culminating skepticism of Hume stimulated Immanuel Kant (German, 1724–1804) to carry through the most profound inquiry into the nature and possibility of knowledge in the whole history of philosophy. Hume must be wrong somewhere, for knowledge actually does exist in the propositions of mathematics and physical science. A new and deeper investigation of knowledge, of mind, and of nature is demanded. Kant asked first: How is knowledge possible? And he carried through what he himself called a Copernican revolution in philosophy by making the constructive activity of the mind rather than objective nature the starting point and foundation of metaphysics. We cannot trace the long line of fertile philosophies which resulted. The principles of Berkeley, Kant, and others have developed into a philosophical standpoint which has taken many names and still more forms (spiritualism, idealism, mentalism, personalism). It is the third type of metaphysics to which we make reference.

The meaning of *idealism* in current speech is determined by that of *ideal,* taken in the sense of a pattern of excellence or a standard of value. But *ideal* is an adjective formed from the noun *idea,* the original root of which is *id-,* from the Latin word *videre,* meaning *to see.* Idealism, then, as a metaphysical doctrine literally means a theory of reality in terms of ideas. The original meaning of *idea* as " visible form or appearance " has gradually broadened. With Locke, as we have seen, *idea* meant any object of perception or thought, and the task of philosophy became the exploration of the world of ideas in its totality. This study included everything which in any way reveals itself in thought, feeling, or action, in science, art,

[4] Hoernlé, R. F. A., *Idealism as a Philosophical Doctrine,* Ch. II and III; copyright 1924 by the Macmillan Company. Reprinted by permission.

morality, or religion; in short, in mind or experience taken in the widest sense.

The idealistic philosopher starts, as he must, from experience taken in the most comprehensive sense. It includes everything within the vast ranges and possibilities of awareness. If we try to avoid experience, we have nothing to talk about, for we can know nothing which does not somehow affect our experience. But experience is not to be defined at the outset so as to commit one to any particular type of philosophy. Experience merely indicates, in the most general way, the proper subject-matter of philosophy; namely, all that is or may be. The philosopher may assume nothing else, or more, than this totality. His task is to interpret experience in terms which have the greatest significance for human life.

Philosophical idealism, in general, is the theory that everything in the universe can be explained in terms of mind and its ideas. " Mind is the hero in every idealistic story." [5] The structure or form of reality, the idealist thinks, is idea, and its content is everything that the individual observer or self is able to put into it, such as color, temperature, substantiality, beauty, and so on through the categories of knowledge. The activities, purposes, and perceptions of mind, cosmic and human, are the roots of reality. Patrick declares: " In general these various forms of modern idealism regard the world as essentially spiritual, rational, intelligible, transparent to our reason, having moral significance. More particularly, the world is some kind of organic unity, having internal relations such that the whole is determined by the parts, and the parts by the whole. Hence results a final unity with harmony in diversity." [6] We shall discuss only two of the many varieties of idealism.

The fundamental proposition of *absolute idealism* is that reality is an absolute mind, an infinite or unconditioned experience. Everything else is a part or an " appearance " of this ordered and self-contained whole. The mechanical laws of nature are the manifestations of cosmic intelligence, evidences of the systematic control of an all-pervading mind. " Whatever is, is rational." The human self is viewed as an aspect or phase of the world-will. In short, the universe is " an infinitely complex network of interrelated elements." One of the chief arguments of the absolute idealists grows out of a theory of truth; if " truth is one coherent system, so reality must be one coherent system. Only a mind, it is argued, could be such an individual whole as our logical ideal requires that reality shall be." [7]

The critics of absolutism have been numerous and varied in point

[5] *Op. cit.*, p. 54.

[6] Patrick, G. T. W., *Introduction to Philosophy,* Boston, Houghton, Mifflin, 1924, p. 249; quoted with permission of publishers.

[7] Brightman, E. S., *An Introduction to Philosophy,* New York, Holt, 1925, p. 243; quoted with permission of publishers.

of view. Some declare that it is too grand a conception for the limited knowledge which we now possess. Further, the doctrine that nothing can be truly known until we grasp its relations to all else is an impossible requirement to fulfil. Other critics say that the absolute, or experience in general, is an abstraction of the same kind as matter. Experience as we know it always exists as the particular experiences of an individual or a self, but a self is not the attribute or adjective of any other self; nor a blend of the experiences of many individuals; nor can it be reduced to an ideal system, although what it does may be systematic. Rather, the self is an original source of productive activities, the supporting and abiding center of experience. LeSenne declares:

> Every metaphysics and idealism are laws of construction, but every law of construction is possible only so far as the activity of a personal consciousness intervenes in order to specify and to organize its application.[8]

This direction of criticism has been organized in the radically humanistic form of idealism known as *personal idealism*. A leading personalist, E. S. Brightman, declares: " Personalism is the name of any theory that makes personality the supreme philosophical principle."[9] *As absolutism emphasizes cosmic system, personalism emphasizes personal values.* This philosophy is frankly anthropomorphic and relativistic in standpoint and principle. A distinguished representative of this view, Borden P. Bowne (1847–1910), declared before the Universal Exposition at St. Louis:

> In the field of metaphysics proper I note a strong tendency toward personal idealism, or as it might be called, personalism: that is, the doctrine that substantial reality can be conceived only under the personal form and that all else is phenomenal. This is quite distinct from the traditional idealisms of mere conceptionism. It holds the essential fact to be a community of persons with a Supreme Person at their head while the phenomenal world is only expression and means of communication.[10]

Personalism is named from the fact that personal intelligence or the self is postulated as the key to reality. The self is the center of experience, the thinker of objects, the bearer of values. The personalist finds his own volitional activity to be the type of causal reality, and advances reasons for supposing that the ultimate cause of our perceptions is a creative intelligence resembling our own, but possessing a power and wisdom proportion-

[8] LeSenne, R., *Introduction à la philosophie*, Paris, Alcan, 1925, p. 314.

[9] Brightman, *op. cit.*, p. 208.

[10] *Congress of Arts and Science*, Boston, Houghton, Mifflin, 1905, Vol. I, p. 172.

ate to the grandeur, order, and beauty of nature. Reality, then, is primarily a plurality of individual selves, " a federal republic of spirits," as Howison described it.

Personal is not synonomous with *subjective* (although the self has a subjective phase), for personal experiences, such as perceptions, possess an objective validity. Unlike private dreams, our genuine perceptions reflect a common-to-all world, a world which others may perceive also. Because our perceptions usually originate independently of our wishes and expectations, and are subject to certain uniformities, we infer that they have a source other than ourselves.

The nature of this source is one of the most ancient and perplexing of all metaphysical problems. We have noted the solutions of naturalism, dualism, and idealism. Realism is a fourth answer to the effect that reals or substances subsist in their own right, independently of mind, and that true ideas are in some way copies or representatives of these prototypes. The personalist contends that such a realm is unknowable, meaningless, and superfluous. He denies that there is any necessary resemblance between our objects of knowledge and their source. The question is one of causation rather than of likeness. He holds the source to be a cosmic mind, a unitary intelligent agent, which acts upon all finite selves. Phenomena appear in the conscious and productive response of the latter. The world ground is the cause of the phenomena which we apprehend as effects. Thus, through a joint activity, the realm of nature is constructed. As G. H. Howison declares, " Every mind thus belongs to the order of first causes."

According to personalism, then, reality has two forms or phases: the phenomenal and the personal; the world of appearance or effects, and the world of productive or personal causes. In short, *reality is a community of selves together with the common phenomenal order they construct and know under the stimulating control of a supreme cosmic mind.*

3. Aspects of the Self

If the personalist is to establish his hypothesis that the self is the key to reality and the ground of all values, clearly he must work out a well-validated conception of the self. A similar requirement obviously applies to whatever principle a philosopher finds fruitful or interesting to postulate as his starting point. While a well-tested view of the self may be the logical basis of a personalistic philosophy, that idea need not actually come first in the historical development of one's philosophy. Indeed, it cannot well come first for the reason that everything that man does and knows reveals his nature and interests. Hence, a metaphysician must have a wide knowledge of life and the world before he possesses the materials out of

which to build a clear conception and appreciation of what man is and of what he may become. The philosopher, therefore, is ever conscious of the incompleteness of his evidence and the consequent tentativeness of his theories. His theories are always subject to the wiser criticism of others or of himself. Man's nature and destiny remain, however, the foci of philosophical interest. It is evident that they are intimately connected with the nature of what is commonly called the external world. The provisional theory of the self which follows will furnish a key both to the branches and to the methods of philosophy which remain to be discussed.

(*a*) What is the relation of the self to experience, that inexhaustible mine which the philosopher must take for granted? Human experience does not exist in a collective or general way, but always in individualized form. It always belongs to someone or to some subject which may be called a self. The human self is an individual finite center of experience which manifests itself in an ever-changing stream of activities. Its experiences have a warm intimacy and inalienable concreteness which cannot be shared with any other person. It is only imperfectly and by analogy that one self apprehends the inner life of another. This fact of ownership and empirical unity occasionally comes to light in that marvelous power of self-conscious reflection of which the self is capable.

In the first place, then, *the self is in part this total conscious life of the individual.* This aspect of the self with its concrete richness we may call the *empirical self.* Although each self is unique, it has some qualities which are common with other selves, which thought may abstract and build into a more or less exact concept of the self. It is these general characteristics of a normal adult human self which we are now endeavoring to set forth.

(*b*) No momentary experience, however, is so vast in its sweep and significance as to encompass the whole meaning of any self. The narrow span of memory and attention shows that the self is far more than this self of the living instant. The self of the moment is continuous with a long past partially reflected in memory and it is continuous with a precarious, perhaps rich, future which is indicated by its present tendencies and wishes. The self, then, has a measure of identity or permanence amid its changing phases. It is in small part the present immediate experience; it is in large part a set of dispositions and aims which its history has gathered into itself and which indicates the unrealized potentialities of its future achievements. This phase of *the self with its developing history and ideal reaches may be called the historical self.* It is the empirical self lived out and thought out. Indeed, all history may be regarded as an account of what the self constructs by its power of representing its own duration in the form of memory.

This notion of the historical self opens vast fields of attractive investigations, for to know what is in man, the inquirer must examine all the

phases of his activities and interests. The most powerful of these, food and sex, concern the preservation and perpetuation of his bodily life. The origin of the vital urge which drives him on is an unsolved mystery. A many-sided education grafts upon his inherited dispositions a host of other desires and purposes. In the course of time he becomes "civilized," self-conscious, sophisticated. He may win, too, a measure of self-determination and take his destiny more completely into his own hands, sometimes to his destruction. To act is inevitable to man, but to act wisely is uncommon. The well-developed self, then, is a complex set of natural impulses and acquired tendencies, memories, and purposes which are more or less organized around a few dominating interests, rarely a single one. In short, man is what he does and desires: he is the whole body-mind active in its various ways: perceiving, enjoying, willing, thinking, aspiring.

(*c*) In our progressive search for the self, we have gained a new notion of its empirical and historical phases. We need to inquire now what these phases imply and how *the self as a whole* may be conceived. The aspects of the self which we have described presuppose and require an enduring active subject which has experiences or which produces a personal history. *The real self may be conceived as an intelligent, willing, valuing agent which acts through a long history in multifarious specific ways in connection with a definite physical organism.* The self, however, is not a mere bodily organism, nor is it bare agency: these are abstract aspects of the living whole which it is. In bodily behavior the volitional subject finds rich avenues of expression and of communication with other selves. It is the concrete individuality and the volitional causality emphasized by the preceding explanation which the personalist takes as two essential marks of reality.

The preceding description of the self has been exceedingly sketchy. It needs to be supplemented in many directions. One of the characteristic tasks of the philosopher is to bring together the chief results of all existing studies of human nature and so to synthesize them as to exhibit the real human self in its wholeness. We can only summarize, in the following paragraphs, the fields where the philosopher may expect to find the most illuminating data. In solving another problem he would, of course, look for materials in a different set of sciences.

The *creative intelligence* of man is manifested in the sciences, philosophies, arts, and social institutions which he has produced. The world of empirical knowledge is the concreted activity of selves. Psychology, anthropology, and history are direct searches for what human nature is and does. It is characteristic of man to strive to remake his environment according to his desires. To facilitate this conquest of nature, he devises various potent machines, concepts, laws, and social organizations — in short, he

exercises his intelligence. By man's intelligence we mean his power to learn to grasp objects in their relations and to regulate those objects to suit his purposes.

His intelligence attains freest expression in the imaginative realm of the fine arts. These afford opportunities for the most nearly adequate expression and development of his *wealth of wishes and emotions.* In the poetry, drama, romance, painting, and sculpture of the ages great personalities reveal to us new aspects and forms of our many-sided human nature. Man also is *religious,* and in his religions he has recorded his hope that the values he esteems may be safely conserved amid the ceaseless changes of circumstances. To realize this end, he seeks friendly and harmonious relations with what he regards as cosmic divinity.

Man is essentially *social.* In his friendships, hatreds, and benevolences, in his economic, political, military, religious, and other social institutions, varied important characteristics of his nature are exhibited. In his legal and moral codes are written something of what he and his ancestors have regarded as good and bad in *conduct.* In man's effort to realize these varied ends he reveals his *deeply dynamic nature,* and it is only through its activities that we can know what the self is. In the light of all his achievements, the philosopher must describe as accurate and complete a picture of human nature as he can.

4. The Branches of Philosophy

We are now prepared to describe the branches of philosophy. In the end, a philosophy represents a systematic expression of the values which the thinker finds most important. The unity of such a system is found in the fact that all values have their source in the self. That only is good and great which the self regards as such. The fundamental interests of the self were summarized in the preceding paragraph. These basic values are cognitive, esthetic, ethical, and religious values. Other types of value fall under one of these heads. The systematic investigations of these principal types of worth constitute the branches of philosophy: logic, esthetics, ethics (including social philosophy), and the philosophy of religion. The fundamental branch of philosophy is metaphysics, which investigates various basic problems, including the interrelation of the other four branches. The aim of metaphysics is truth; it does not deal with a special kind of value, unless we agree with certain Catholic metaphysicians who hold that to be, with all that this means, is the fundamental good. The sixth and last branch of philosophy (which may as well come first) is the history of philosophy.

The divisions of philosophy are in part answers to the six great questions which follow. What can we know? What may we enjoy? What ought

we to do? What may we hope? What is real? What have the wise men of the past believed? The following treatment of the several philosophic fields may be brief, since previous chapters have dealt with ethics, esthetics, and the philosophy of religion. Part II of the book sets forth the chief problems of logic.

(*a*) The philosopher is severely critical of his assumptions and tools of research. As his way to truth, he adopts persistent reflection about experience. To avoid illusions and errors, he needs to know the nature and limitations of thinking. His first step, therefore, is a thorough examination of the activity of thought itself. The traditional name for such a critical study of thinking is logic. *Logic* is used here broadly to include three studies: (1) the most general principles of conception, inference, and order (formal or symbolic logic); (2) the nature and conditions of knowledge, especially the relation of the mind to the object known, the criteria of truth, and the laws of evidence (epistemology); and (3) the methods of obtaining knowledge in scientific investigations (methodology). Many thinkers, with good reason, prefer to regard epistemology as a distinct branch of philosophy. In short, *logic is the systematic study of the principles and rules of true thinking.* Thinking includes every mental activity directed toward attaining knowledge.

(*b*) *Esthetics,* as we have seen in Chapter XVIII, *is that branch of philosophy which studies art and beauty in all their countless forms.* Philosophy and art have a close kinship; each is a source of understanding for the other. As an artistic work is an ordered product of the imagination expressing some significant impression, vision, or emotion of the artist, so a philosophy is a thorough-going effort of the mind to achieve a harmonious picture of which the cosmos itself is the theme. The philosopher endeavors to explain or overcome the disharmonies of experience and to construct a consistent and satisfying view of the world in whatever terms seem to him most true and adequate.

But in determining what is satisfying and adequate, he cannot entirely eliminate his own temperament and postulated set of values. The principles and standpoints of his system reflect his personal selection of what is significant in experience. Indeed, this selection, with its reasons, is the most interesting and important part of his system. A philosophy, then, is like a work of art in that it is an orderly representation symbolizing its creator's interpretation of reality. It is the most perfect fitting together of the varied phases of life that the philosopher can attain with his best knowledge and insight. A philosophical system differs from a work of art in that it has conceptual form, is comprehensive in character, and claims a measure of validity.

(*c*) Ethics, as we have seen, is another important philosophical

discipline. It is a systematic study of the nature and ends of conduct. It includes an investigation of such problems as those of justice and injustice, goodness, happiness, conscience, and duty. Indeed, since any kind of good whatever may become moral by being approved or chosen, *ethics is well conceived as the general theory of value,* an axiology, the purpose of which is to make a comprehensive study of the goods that men esteem, of their varieties, conditions, and interrelations. Such an investigation brings within philosophical consideration various forms of value other than those we have mentioned, such as health, wealth, recreation, and social values; for example, power, fame, and friendship. Ethics, then, includes an economic and social philosophy. In the end it becomes a philosophy of civilization, a theory of human well-being and culture, a philosophy of history.

(*d*) The philosophy of religion is a free and critical study of religion in all of its principal aspects. We have seen how the main problems of this branch of philosophy concern the nature of supreme reality, regarded as divine, of man's relation to that reality, and of human society and destiny as affected by that relation. The philosophy of religion has much in common with metaphysics. The metaphysician, in his search for a comprehensive grasp of reality, must include religious experience and a theory of God. On the other hand, the theologian, dominated by an interest in the conservation and creation of human values, cannot wisely avoid giving a metaphysical foundation to his views.

(*e*) *Metaphysics is the critical study of reality in its most general aspects.* It is concerned with such questions as the nature of being, space, time, causality, mechanism, purpose, evil, mind, value, and cosmic order. The theory of knowledge is preliminary to metaphysics, but metaphysics remains the most fundamental of all branches of philosophy.

(*f*) In this search for the meaning of things the philosopher needs a keen historical sense, a discerning susceptibility to the great historical movements of life and thought. He inquires what the sages of the past have said concerning the enigmas of life with which he is wrestling. One who has not lived in the republic of Plato, searched with Aristotle or Hegel for the first principles of things, experienced the Copernican revolution with Kant, or lived with Spinoza *sub specie aeternitatis,* has missed looking at the world through some of the grandest windows which human reason has opened to illuminate man's primitive darkness. The great historical advances in natural science, religion, art, politics, and geography may bear upon the philosopher's problems. He strives also for an appreciative understanding of the main contemporary tendencies in these and other fields of life. The philosopher, then, often begins the study of a question by ascertaining what has been said about it in the history of

thought. The *history of philosophy as a critical interpretation of the thought and life of the past* is another important branch of philosophical research.

5. The Synoptic Method of Philosophy

The aim and task of philosophy determines its method. The philosopher seeks a comprehensive, reasoned interpretation of life and the world, and welcomes any procedure which promises in any way to aid his difficult enterprise. We shall not discuss in detail how the philosopher employs induction, deduction, and other familiar and valuable methods of science. We shall confine our attention to that method which we regard as characteristic of philosophical investigation. There is no single name which is adequate to designate it; perhaps the best is the *synoptic method* described by Brightman, Hoernlé, Sorley, and others.[11] It may also be called philosophic criticism or philosophic interpretation. It is a highly developed form of teleological explanation as described in Chapter XVI.

The term *synoptic method* goes back to Plato's use of *synopsis* to mean "the seeing of anything all together in one view." For him the highest form of thinking "is the comprehensive intuition of the man who sees all things as parts of a system, realizes that each part has its being in the whole, and brings that system to bear on each thing."[12] This power of the mind to give clearness, order, perspective, and value to the concrete experiences of life is sometimes called *reason.* It is the analyzing, organizing, and interpreting activity of the mind. Creighton thus beautifully describes it: "Reason is on the one side just the transforming power of the mind in action, striving towards a more systematic and significant world of experience, and on the other the power of conceiving as elements of that world the results already obtained. . . . *Reason,* as Hegel has said, *is the medium in which all the elements of our experience . . . . find their place as living parts of the whole.*"[13] The synoptic method means rational interpretation thus defined. It is the most ambitious and the most difficult of all methods of knowing. We shall now point out several phases of this method as it is practiced by philosophers.

(*a*) The Need of Much Knowledge and No Prejudice. — The synoptic method is as much a spirit or attitude of mind as it is a set of logical rules. Therefore, as we proceed to indicate some of its aspects we shall really be describing the philosophic spirit. If we are to give proper weight to every consideration bearing on an issue, we must avoid, so far

[11] *Cf.* Brightman, *op. cit.,* Ch. I, sec. 11; Hoernlé, R. F. A., in *Contemporary British Philosophy,* second series (Muirhead, editor), New York, Macmillan, 1925, pp. 131–156.

[12] Brett, G. S., *History of Psychology,* London, Allen, p. 82.

[13] *Philosophical Review,* Vol. XXX, pp. 469–482; the italics are ours.

as possible, every prejudice which might exaggerate a single factor. The first rigorous demand of the synoptic ideal, therefore, is the demand for as complete an elimination as possible of dogmatism, bias, uncriticized assumption, and everything which might distort one's view of life.

This ideal is not easy to realize. Two sources of prepossessions need especially to be guarded against. The first is long association in particular social groups, notably economic, political, national, and religious communities. A second frequent source of bias is expert training in a special science or art. If a thinker enters the temple of philosophy from the vestibule of a particular science, he is in danger of assuming the favored set of data or point of view of that science and then of reducing everything else in the universe to that set of data. A physicist or physician is likely to come out with materialism or dualism, a biologist with vitalism, a theologian with idealism, and an artist with romanticism.

The fear of dogmatism may itself become a bias, an exaggeration, or even a skeptical metaphysics. Such a prejudice is illustrated in the proud irreligious attitude which is sometimes paraded abroad. The true philosopher humbly seeks open-mindedness, the exposition of all assumptions, and disinterested contemplation. The categorical form of his statements — simple and convenient — and his enthusiasm for his study sometimes conceal the caution and humility which he feels at heart.

The ideal of the philosopher is to see all through and around his problem. For this purpose he strives to be, in Platonic terms, a "spectator of all time and existence," a well-instructed citizen of the world. "Philosophy makes a resolute effort to do justice to *all* the facts, and not to slur or ignore those that are distasteful or inconvenient."[14] The philosopher neglects nothing which may be relevant; and, *a priori,* there is nothing which may not in some way be relevant, for his subject-matter is everything. His consideration of pertinent material is as thorough and all-inclusive as he can make it. When his treatment of a subject cannot be complete, he strives to make it well-balanced. He seeks data and suggestions from any source whatever that promises illumination. Everyday experience in all its vicissitudes, the regiment of the sciences, history, and art, may furnish germane subject-matter. The richer his personal experience, the wider his travels and social sympathies, the more extensive his knowledge of institutions and world-views, the better prepared he is for discovering and developing the significant interpretations of life which he seeks. It is this endeavor to see a problem from every point of view which Hoernlé emphasizes in his delightful exposition of the synoptic method.

(*b*) Regressive Criticism. — Even a cursory acquaintance with nature, man, and society shows that facts are habitually related. Every phe-

[14] Announcement of the British Institute of Philosophy, p. 8.

nomenon is found to be somewhat connected with many others, and in the end, with the universe. The philosopher, therefore, might start with any fact of experience and proceed to explain it by bringing to light all that is involved in it. The philosopher must, of course, assume that there is a world of some sort and that experience is somehow possible. Some ideas, however, are more useful and significant as starting points than others. Conception, knowledge, mind, causality, substance, change, and justice are some of the fruitful problems with which philosophers of the past have begun their investigations.

Another phase of the synoptic method is this search for all of the essential factors and presuppositions of a given experience. This search has been called regressive criticism, or the reflective method.[15] It means taking some problem and tracing, step by step and in all directions, the facts and principles which bear upon it, or which are implied by it, until the fullest possible meaning has been given it.

We have illustrated above how the implications of the self may be traced out by the regressive method. Let us apply for a moment the same method to the idea of doubt. Since every philosopher at some time or another entertains doubts concerning his views, he needs to inquire what doubt is, and why it is important. It has a psychology and a logic. It is surrounded with prejudices and fears. It involves certain assumptions. One cannot completely deny the existence of truth without presupposing much. To declare there is no truth is self-contradictory. Augustine pointed out one interesting implication of doubt. He said, " I doubt; therefore, I am "; that is, unless there exists a being capable of reasoning and doubting, doubts and mistakes are impossible. Royce, in his book, *The Religious Aspects of Philosophy,* suggested the minimal assumption that " error is possible." Even the rankest skeptic could accept such an assertion. Yet Royce attempted to show that the explanation of how error is possible leads one on to a system of absolute metaphysics. Many a philosopher has been wrecked on the hard question, How is error possible? Ideas and objects, then, seem to hang together, and the existence of one involves others.

The limits of regressive criticism set the limits of metaphysical explanation. Since the philosopher takes all reality to be his province, he obviously cannot go outside of the universe to find principles to explain it. His task is rather to make plain what the world is in itself by exhibiting its inner structure and processes. Philosophy is the systematic explanation of reality.

(*c*) The Search for a Coherent Interpretation of the World. — The regressive method is mainly analytical and fact-finding in nature.

[15] *Cf.* Avey, A. E., *The Function and Forms of Thought,* New York, Holt, 1927; see pages 37–40, 51–52, 79–81, on " The Method of Reflexion."

Its needed complementary is the *synthetic method* by which the results of analysis are organized into a harmonious whole. These two methods are aspects of the single progressive search of the philosopher for a coherent or synoptic view of the world. We separate them here only for purposes of exposition. The synthetic method (sometimes called dialectic) consists in exhibiting, in as clear and organic a way as possible, the way in which facts really hang together. A philosophic synthesis is to be self-consistent, supported by cogent reasons, and contradicted by nothing. Bosanquet has declared, " I only know in philosophy one method; and that is to expand all the relevant facts, taken together, into ideas which approve themselves to thought as exhaustive and self-consistent."[16]

Non-contradiction is the first law of thought in philosophy, as in all other thinking. Contradictions are signs of error. They must somehow be removed or explained. They may be due to partial knowledge of relevant facts, to a false statement of the problem, or to overlooking facts of change and development. The philosopher is dissatisfied so long as any germane fact remains to contradict his working hypothesis.

In order that he may avoid inconsistencies or narrowness, the philosopher invites criticism from every quarter. He shows a " frank and unlimited hospitality for every conceivable objection." If his best critics agree with him, he suspects too easy a victory. Those who differ with us are the ones who are likely to do us most good. They require us to examine our opinions and think farther than we might without their opposition. The philosopher has to overcome that natural human pride and laziness which stand in the way of this lofty state of utter impartiality and pure love of truth which can delight in all criticism. He strives for propositions that will be free from contradiction and which will withstand every assault. Philosophy is a strenuous pursuit.

In the process of eliminating ambiguities and inconsistencies, we often find that we must revise our body of knowledge; we pass to a synthetic interpretation of the world. The criterion of coherence is the positive complement of the law of non-contradiction. It is the postulate that the more clearly, broadly, and organically we grasp the factors and relations of anything, the more truly and really we know it.

We win philosophic insight when we clearly grasp a concrete individuality in its cosmic setting. The nature of individuality was touched upon in the chapter on esthetics. Anything that has integrated elements, a functional variety in unity, is an individual, whether a drama, a living organism, a printing press, a governmental bureau, the human self, a molecule, or the universe. Thus, we understand a particular human self when we

[16] Bosanquet, Bernard, *Lectures on Aesthetics,* p. 3; copyright 1915 by the Macmillan Company. Reprinted by permission.

know its multifarious activities and see its place in the historical, physical, and spiritual worlds. Individuals seem to gain richer meanings as they enter wider relationships. A particular thing which has no relations with anything else is meaningless; indeed, is nothing at all. On the other hand, to know all that is involved in the " flower in the crannied wall " is to understand the universe. It is in the integrated totality of standpoints from which an object may be viewed that we are most likely to discover what it really is. Philosophy is a radical endeavor to grasp things in the ordered perspective of the whole to which they really belong. It is a thoroughgoing attempt to satisfy the mind's double demand for concreteness and for completeness in understanding the world.

There is one important factor in philosophical criticism which idealistic philosophers especially have emphasized. Josiah Royce called it " interpretation," and elaborates it in his distinction between the world of description and the world of appreciation. The term *interpretation* comes from the field of literary exegesis where a teacher endeavors to translate symbols into a language which will communicate significance to an expectant learner. It is essentially a social enterprise, in which one mind strives to enter into the meanings, purposes, and estimates of another mind. It plays a large part not only in literary, dramatic, and theological studies, but in every field of social intercourse. Schleiermacher and his school of theologians have emphasized the importance of gradually and progressively " feeling one's way " into the inner life of a religious community. Thus Schleiermacher urges, " You must transport yourself into the interior of a pious soul and seek to understand its inspiration; otherwise you can learn nothing of religion."

Interpretation is the sympathetic appreciation of the values esteemed by another personality. By this mental process we understand, more or less, the crying of a child or the character exhibited by a great dramatic actor. Interpretation is more than conceptual learning or logical synthesis; it is, too, more than perception or imagination; it includes all these but adds to them a closeness of personal touch, a vivid grasping of the significance of the living interests or purposes which possess another self. Interpretation is the highest form of teleological explanation and the culminating point of philosophic insight. It is the method by which the philosopher endeavors to solve the fundamental problem concerning the nature of value.

(*d*) Progressive Revision. — In a changing world like ours, a philosophy always remains subject to revision in the light of growing experience and knowledge. Thus, philosophy is always tentative, always in the making, as life itself is always in the making. Few understand so clearly as the philosopher how vain it is to look for ultimate knowledge of any sort. The youthfulness of the human mind and civilization, the

striking vicissitudes of history, the unpredictable discoveries of the onsweeping centuries, all make the wise man humble and ever ready to modify his surest conceptions. Just because philosophy is both comprehensive and systematic in nature, because it is the expression of the whole movement of life and civilization, the discovery of any important new fact or standpoint may affect it somewhere and call for the reëxamination of the whole, from its foundations to its conclusions. Hence, fresh starts are necessary in philosophy oftener than in any other study.

Another phase of the synoptic method, therefore, is progressive revision. This is another expression of the open-minded and progressive spirit which marks truly philosophical research. It follows that discussion and the world-wide interchange of ideas are the very life of philosophy. Great philosophies develop under the mutually stimulating criticism of many minds bent on truth. As soon as any philosopher declares that his system is final and mandatory, he becomes unphilosophical, and often uninteresting to the real truth-seeker. So long as human experience keeps on expanding, philosophy will keep on growing.

The chief characteristics, then, of philosophical knowledge are that it is progressive, fundamental, comprehensive, systematic — in short, synoptic.

6. Science and Philosophy

Philosophy is distinguished from science by its use of the synoptic method, especially by its regressive search for first principles and its interpretations of value. *Science describes; philosophy evaluates.* The particular sciences, especially the more youthful ones, are not primarily concerned with the general assumptions involved in their investigations. The scientist becomes interested in certain fields of experience, adopts a definite standpoint, perhaps chemical, botanical, or geological, and then endeavors to describe exactly the specific phenomena that are relevant to that point of view. He strives in his studies to be impersonal, disinterested, objective. As a rule, he simply ignores the backlying presuppositions which exist in science as they do in theology, art, or industry. Science is impersonal only through assumption, abstraction, or specialization of study. Strictly impersonal knowledge is a fiction. Knowledge exists only as a form of someone's experience. The scientist ignores the personal factor by assuming that this factor remains constant, that his experience and reasoning are standard for all normal minds. As a scientist, he properly ignores the psychic and cosmic setting of his inquiries. His results, then, are accepted as abstract or partial because of his particular working standpoint.

The philosopher, on the other hand, can ignore nothing. He wants to know about all of the concrete living conditions under which knowledge

actually exists. He makes knowing self-conscious, frank, human. How do human interests and motives affect the pursuit of truth? What are the conditions of getting and having truth? What is the relation of science to other major human endeavors, such as art, conduct, and religion? What is meant by the phenomena, facts, or processes which the scientist studies? How is the object perceived related to the perceiving mind? Are scientific objects and knowledge as objective as they seem? What, in short, is the full meaning of the act of knowing, of truth-getting? The scientist may pass by questions concerning the nature of validity, order, causality, time, selfhood, value, or method, but the philosopher is most interested in such questions. He wishes to see all that is involved in any problem that he takes up.

As soon as anyone, scientist or philosopher, asks what basic assumptions underlie any field of activity, he raises a philosophical question. Several advanced sciences in recent years have become more and more philosophical in character. Modern mathematics, for instance, exhibits a philosophical aspect in its systematic search for fundamental presuppositions. In the chapter on mathematics we noted how the foundations of mathematics and logic have become the same. Modern physics, too, in its effort to get at the bottom of energy, has come face to face with the problems of the nature of time, space, activity, perception, etc., with which philosophers have been long concerned. Numerous modern scientists, in searching for the wider bearings of their subjects, have become notable philosophers, for instance William James (psychology), A. N. Whitehead and Bertrand Russell (mathematics), and L. J. Henderson (biochemistry). Philosophy and science are not antagonistic, but essentially supplementary. They profit by coöperation, since each may contribute materials and methods of study to the other.

7. The Value of Philosophy

The preceding study of philosophic method has indicated something of the spirit and purpose of philosophy. As the philosopher attains a deeper grasp of nature and man, he becomes disillusioned, self-conscious, cosmopolitan, and in consequence may win an abiding peace and serenity of life. He throws aside some of the husks of prejudice, triviality, irrelevance, and fear. In some measure he may realize the Platonic ideal of being a "spectator of all time and existence." As he achieves a better understanding of how the world is constituted, he feels more at home in it (hence the kinship of philosophy and religion). As he appreciates more clearly what values are possible to man, he gains a more solid basis for conduct and happiness. If there is any basis for human hope, he may find it; if existence is a sandy waste in an otherwise empty world, he can at least declare with Bradley: "Where everything is bad, it must be

good to know the worst." Justin Martyr put these words into the mouth of one of his characters: "Philosophy, then, is the knowledge of that which really exists and a clear perception of the truth; and happiness is the reward of such knowledge and wisdom." [17]

The practice of the philosophic method as described above tends to create an immense human tolerance. Philosophy is an unequalled discipline in open-minded thinking. It raises the spirit of impartiality to the highest level. It is a radical endeavor to be free from any narrow or favorite set of data. It stimulates that combination of deep humility, hard and patient thought, and enthusiastic exploration which often characterizes great thinkers. While no one else's philosophy is likely to be wholly satisfactory to a philosopher, he eagerly listens to anyone who has reasoned, or reasonable, views about the great problems of life. He is at home with all minds in all lands and in all times. "A wise man knows himself a citizen of the world." He is debtor to everyone he meets, to some much more than to others. To gain a personal acquaintance with the method of Socrates, the idea of Plato or Royce, the pure spirit of Descartes, the world substance of Spinoza, the synthetic activity of the mind set forth by Kant, the vital impulse of Bergson, or the pragmatic test of James, is to find new outlooks of permanent value upon life. One may properly refuse to build one's own house on any of these hilltops, but, having seen the world once from these peaks, one's map of life's landscape can never again be the same. One goes on to other points of view, to other lookouts, in the hope of more and more clearly seeing the relation of each portion of the landscape to all others. Perhaps in the end one may grasp all points of view as factors in a harmonious whole. Only by prolonged and penetrating contemplation, constantly supported by abundant facts, can the whole panorama of existence take on such coherent order that the wise man may find therein a clear and safe guide for living the most abundant life. Philosophy provides the intellectual technique for realizing, so far as possible, this alluring goal.

R. F. P.

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[17] *Dialogue with Trypho,* Bk. III.

APPENDIX

APPENDIX

QUESTIONS AND EXERCISES

PART I. A SURVEY OF THE SCIENCES

Chapter I. The Background of Knowledge

1. Distinguish man's nature from his culture.
2. Why should the loss of all traditional knowledge lead to a catastrophe?
3. Describe each of three typical attitudes to tradition.
4. How do traditional ways of doing things, or inherited modes of thought, facilitate the accomplishment of purposes?
5. What are the disadvantages of restricting oneself to the traditional modes of doing things?
6. If you thought the headgear required by your college were absurd, what would you do about it?
7. What are the steps in the critical handling of traditional data?
8. In what ways should education alter a person's relations to customs, conventionalities, and beliefs?
9. What makes a traditional belief a prejudice?
10. What are the various factors which operate to produce prejudices?
11. What are the characteristics of a good authority?
12. Test the authority of Edison in the field of general education.
13. What is the authority of Biblical writings in the realm of natural science?
14. Why is leadership of the young desirable in society?
15. What are some of the conditions of effective collective thought?

Chapter II. Mathematics

1. Why has mathematics been esteemed as a model science?
2. Analyze the process of measurement into its logically elementary parts.
3. Explain the nature and advantages of our common decimal system.
4. Describe and illustrate the difference between Roman and Arabic notation.
5. Add 23 and 46 and state the sum in terms of 60 as a basis of notation.
6. Explain the superiority of Greek over Egyptian mathematics.
7. What is the significance of Euclid in mathematical history?
8. Explain the nature and criterion of proof in mathematics.
9. What is the historical significance of non-Euclidean geometry?
10. What are the foundations of mathematics? How are various systems of algebra and geometry possible?

11. Criticize Bertrand Russell's definition, proving, if possible, the truth of each part of it: " Mathematics is the subject in which we never know what we are talking about or whether what we are saying is true."
12. Are mathematical postulates set up in an arbitrary manner?
13. Show how modern industry, business, engineering, and science depend upon mathematics.
14. What are the characteristics of good mathematical thinking?

Chapter III. The Physical Sciences

A. Astronomy

1. Explain one way of measuring the circumference of the earth.
2. Point out as many characteristics of modern science as you can find embodied in the work of Newton.
3. In the development of the theory of planetary motions show (*a*) the interplay of tradition and innovation; (*b*) the contribution of each thinker; (*c*) the modes of proof employed; and (*d*) any other scientific methods used.
4. What advantages does the camera possess in astronomical observation?
5. How is it possible to determine the chemical constitution of the sun or of a star?
6. How account for the dark lines in the solar spectrum?
7. Make a list of the facts which we can learn from the spectroscope.
8. What facts point to a material unity in the cosmos?
9. Why suppose that stars evolve?
10. What is the nebular hypothesis? Why accept or reject it?
11. Explain the planetesimal hypothesis.
12. What are some of the main factors upon which progress in astronomy depends?

B. Geology and Geography

13. Make a list of the chief forces which are now altering the landscape.
14. What are the dominant forms of life in the main eras of geologic time? Note the crucial dates. What percentage of time elapsed before man appeared?
15. How may the age of the earth be estimated?
16. How is it possible to determine the nature and succession of life during the early periods of the earth's history?
17. What agencies tend to make the ocean beds heavier than the continents?
18. Explain and illustrate *geological cycle*.
19. What is the theory of isostasy? Mention some evidence for it.
20. Explain and illustrate the principle of uniformitarianism.
21. Explain the influence of bodies of land and of water, and that of climate, upon civilization.

C. Physics

22. Describe the spirit and method of Galileo.
23. Why suppose that material substances are discontinuous or made up of atoms?

24. What are the main points in the atomic theory?
25. How was the charge of an electron measured?
26. What is the significance of Wilson's cloud-chamber experiments?
27. How does natural science aid man in controlling his environment?
28. What are the most important sources of energy in modern industry?
29. Classify Stratton's list of nine wonders according to the sciences involved. How would you amend this list?
30. Explain the part that the velocity of light plays in the theory of relativity. What problem arises from assuming that it is constant?
31. Under what conditions does the length of a yardstick and of an hour change?
32. Do the people who live in Thibet really have a longer day than people who live in Holland?

D. Chemistry

33. What is an element? A molecule? A chemical compound?
34. How does the chemist systematically describe chemical substances?
35. What are the advantages of the chemist's symbolism?
36. Make a list of the basic principles of chemistry.
37. Explain exactly what is meant by atomic number.
38. Upon what basis have the completed atomic shells been estimated?
39. Indicate as many ways as you can in which chemistry affects the manufacture and operation of an automobile.
40. Are geometrical pictures legitimate in the descriptions of physical science? Why or why not?

Chapter IV. Biological Science

1. What are the etymological meanings of biology, zoölogy, taxonomy, and morphology?
2. Point out as many differences as you can between living and lifeless things.
3. State two of the most important generalizations of modern biology.
4. Point out the significance of the cell theory in biological study.
5. Compare the meaning of function in biology and mathematics.
6. What sciences study the distribution of animals in time? In space?
7. Point out several biological factors or elements in evolution.
8. What are the chief evidences for evolution?
9. Point out conditions which have brought the whale to be what it is.
10. How, perhaps, has the giraffe come to have a long neck?
11. What are Mendel's laws?
12. Explain how natural selection operates so as to effect the development of organisms.
13. Describe two antique methods of curing diseases.
14. Mention several of the most fundamental ideas and methods of modern medicine.
15. Mention three of the chief glands of the human body with their respective functions.
16. What are the chief public agencies promoting the health of the community?

17. Point out several concrete ways in which biology may be applied so as to contribute to human welfare.

Chapter V. Psychology

1. What are the aims of psychology?
2. Show how some human activity may be studied by at least four different sciences.
3. Indicate the various fields of psychology.
4. In what respect are the functional, behavioristic, and dynamic viewpoints similar?
5. Mention one defect and one contribution of each of four viewpoints in psychology.
6. State two different theories of human nature.
7. What are the chief types of man's original tendencies?
8. How may human activities be classified? Illustrate.
9. How may native and learned traits sometimes be distinguished experimentally?
10. Describe the establishing of a conditioned reflex. Why is it a very important concept?
11. What exactly are the distinguishing marks of intelligence?
12. Explain what is meant by character, by prejudice, and by rationalization.
13. Of what use in advertising is the knowledge of human nature?
14. What is the basis of wit and humor?
15. How does psychology aid education?
16. How is the *IQ* determined?

Chapter VI. History

1. What is history?
2. Indicate the materials of history.
3. Name and describe the auxiliary sciences of history.
4. What science aims to write the preface to history?
5. Write an essay of three hundred words on *Pithecanthropus;* the Heidelberg jaw; Piltdown man.
6. Indicate the cultural developments associated with Neanderthal man and with Crô-Magnon man.
7. Find out all you can about the differences between late Paleolithic and early Neolithic culture. What do you think happened?
8. Why should there be "textual criticism"? In general what does it aim to do?
9. Illustrate the technique of the literary criticism of a document.
10. What is the significance of the Rosetta Stone?
11. Contrast "primary" and "secondary" sources.
12. What is a philosophy of history?
13. What is the utility of a philosophy of history?
14. Is history literature or science? Why?

Chapter VII. The Social Sciences

1. What was Plato's idea of the "philosopher-king"?
2. Distinguish the fields of politics, economics, and sociology. Why did these social sciences develop separately?
3. Why is social science undeveloped?
4. What are the methods of social science?
5. Define precisely a social "institution."
6. What is the subject-matter of social science?
7. In what sense is the family an institution?
8. Indicate as many functions as you can which can be classified as family activities.
9. What changes are in progress in the family as an institution?
10. Define economics; industry; machinery.
11. What alterations in our habits have been occasioned by the introduction of machinery in large amounts?
12. State and criticize the law of supply and demand.
13. To what extent are production and consumption controllable?
14. What is the significance of the English Trade Board?
15. What is democracy?
16. What are the advantages of democracy? Of aristocracy?
17. Explain revolution.
18. Discuss Aristotle's doctrine of the middle class.
19. Why is war a problem today?
20. How has the rise of middle-class government and of industry changed the character of war?
21. Define nationalism.
22. Discuss the relation of nationality to political structures.
23. What is the significance of the League of Nations?
24. In what sense is there social progress? Illustrate.
25. Why is education a social science?
26. What is the aim of education?
27. What is the aim of scientific method applied to any social institution?

PART II. LOGIC: A PHILOSOPHY OF SCIENCE

Chapter VIII. Thinking

1. What is a science? How differentiate sciences?
2. What kind of unity may be found among the sciences?
3. What are some of the social values of correct thought?
4. Where would you look for materials for a scientific account of thinking?
5. Distinguish three types of learning.
6. What is a concept or universal? What is its function?
7. What are the logical stages in the formation of a concept?

8. Show how conception was necessary to solve the following problem, and what concept? Two men in a leaking boat are saved only by it occurring to one of them to use his companion's hat to bail out the water. Could a dog have solved this problem?
9. How do concepts make for economy and freedom in the mental life?
10. How does the progress of science affect the form of scientific language?
11. What are the advantages of a technical language in science?
12. What would be the characteristics of an ideal scientific language? Would such a language be good for poetry?
13. What is the difference between denotation and connotation? Illustrate by reference to *orange*.
14. Distinguish genetic and etymological definition.
15. Give etymological definitions of: *geometer, psychology, pagan, concept, ambiguity*.
16. Give genetic definitions of: *sensation, circle, athlete*.
17. Give a logical definition of: *book, liquid, democracy*.
18. In the following definitions (*a*) point out one example of each of four kinds of definition, (*b*) find one violation of each of the rules of definition, and (*c*) criticize each:
    a. Hope is a pleasure derived from expecting a future good.
    b. A planet is an opaque body like the Earth, Venus, or Mercury.
    c. The mind is the eyesight of the soul.
    d. Water is a fluid formed by combining one part of oxygen with two parts of hydrogen.
    e. Life is an organized sum of vital processes.
    f. Sensations are "typical constellations of centrifugal irritations of the central nervous system."
    g. Man is a house-building and clothes-wearing biped.
    h. Physics is the science that studies material things.
    i. "A man's life consisteth not in the abundance of the things which he possesseth."
    j. Philosophy, according to its Greek components, means the love of wisdom.
19. What errors in thinking and communication are traceable to the careless use of language?
20. Distinguish concepts from percepts.
21. Criticize the contrast between *existence* and *subsistence*.

Chapter IX. Observation

1. What steps in an act of thought involve observation? Why?
2. Define and illustrate *fact*.
3. How do we arrive at *data?*
4. Do we ever deal with *pure* fact? Why?
5. Comment on the part observation played in the development of the theory of the Glacial Age.

6. What part did observation play in the discovery of Halley's comet? Of anesthetics?
7. Give a detailed account of one of Newton's experiments, pointing out the characteristics of his method.
8. Why was Goethe's attack on Newton ridiculous?
9. Discuss the hindrances to scientific observation.
10. Describe the observations of Coolidge and Millikan.
11. Why are accurate instruments and accurate records an indispensable part of scientific observation?
12. What is the significance of control in experimental observation?

Chapter X. Judgment and Inference

1. What is the purpose of logic? How does it resemble other sciences?
2. What is the essential function of judgment?
3. Show how thinking is both analytic and synthetic.
4. Explain the concept of orange in terms of the theory of judgment.
5. What kind of a world does thinking presuppose?
6. Explain and illustrate exactly what is meant by inference.
7. Do true and false judgments have the same logical structure?
8. Describe and illustrate implication.
9. How is inference related to system? Illustrate.
10. Make a list of the characteristics of the good thinker.
11. In the light of this chapter as a whole, explain what is meant by knowledge.
12. What is the function of thought in relation to experience?

Chapter XI. Induction

1. What exactly is the problem of induction? Illustrate.
2. Explain why induction would be impossible in a world without order.
3. Why is the enumeration of instances an incomplete account of induction?
4. If the postulate of sufficient reason is true, how explain so-called chance events?
5. Many years ago, when the French and English were at war, a violent storm drove an English merchant ship into a French port, and the French sank it with a cannon. The English owners sued an insurance company for the payment of the insurance which they had on this ship against loss by storm. Determine precisely what was the cause of the sinking of the ship.
6. Explain and illustrate the postulate of limited conditions.
7. In connection with each of Mill's five methods: (*a*) fix in mind the principle or canon; (*b*) discover or note one example; and (*c*) note at least one defect or limitation.
8. How prove whether or not coincident phenomena are really causally connected?
9. What principle or method guides in scientific experimentation?
10. Explain two criteria of irrelevance.

11. In the following table the capital letters represent antecedents and the small letters consequents; determine two causal connections by applying Mill's methods; name the methods employed:

1. ABDE . . . pqst		5. HK . . . xqr	
2. BCD . . . qsr		6. ABFG . . . ptuv	
3. BFG . . . vuq		7. ABC . . . pqt	
4. ADE . . . tsp			

12. Define and illustrate each of the five chief types of inductive fallacies.
13. How may the defects of the method of agreement be overcome?
14. Criticize the statement: the validity of a generalization is in direct proportion to the number of instances examined.
15. When are many instances necessary for a generalization? When few?

Miscellaneous Examples of Induction

Estimate the degree of probability in the following arguments and find as many methods of Mill, other scientific methods, and fallacies as you can:

16. Lavoisier observed that a definite quantity of phosphorus burns in a definite quantity of air, that combustion will not take place when the air is exhausted, that a new piece of phosphorus will not burn in this air, and that the volume of the air is diminished while the weight of the solid material is increased. He concluded that oxygen is the cause of combustion.
17. Van Helmont (born 1577) reasoned that plants obtain all their constituents from water because a willow weighing 5 lbs., planted in 200 lbs. of earth, gained, in five years, 164 lbs., while the earth lost only 2 oz.
18. In 1924 goitres were more prevalent in Michigan than were Fords. A state-wide campaign put iodized salt in every home. Today the condition is not only singularly rare among school children, but not a single baby has been born with goitre when the mother had been using iodized salt.
19. Pascal observed that the height of a column of mercury decreased with its altitude. He inferred that the atmosphere, and not the horror of a vacuum, was the sole cause of its suspension.
20. The planet Mercury rotates on its axis; so do Venus, the earth, Mars, Jupiter, Saturn, Uranus, and probably Neptune. But these constitute all the planets. Hence, all the planets rotate on their axes.
21. Robert Marshall has noted that between 1825 and 1924 every drier-than-normal four years (notably the periods prior to 1828, 1884, and 1912 — Jackson, Cleveland, Wilson) was followed, with two exceptions, by the defeat of the political party in power. He declares also that, with only one exception, a wetter-than-normal four years heralded continuance in power. Drought forebodes political upheaval.
22. In 1893 Rayleigh noticed that nitrogen from the atmosphere has a density of 14.07 while nitrogen produced in the laboratory has a density of 14.005. In the next year Ramsay proved that the atmosphere contained small quantities of an unknown heavy element; it was named argon.

23. Until the end of the eighteenth century scurvy was a terrible scourge for seafarers. It was supposed to be due to exposure to cold in northern climates, to sea air, to salt meats, or to other causes. Bachstrom in 1734 observed, however, that "where persons, either through neglect or necessity, do refrain for a considerable time from eating the fresh fruits of the earth and greens, no age, no climate or soil are exempted from its attack. Other secondary causes may likewise concur, but recent vegetables are found alone effectual to preserve the body from this malady." (G. Spiller)
24. The following test was made some years ago in the Swedish army. A group of soldiers was divided into two parts. The first were given each day as much alcohol as is contained in 1¼ pints of beer, and the other part were given none. Then they were tested for endurance in rifle shooting. The first group became exhausted on an average after 277.5 shots; the second group, after 359.5 shots.
25. The last gas to be reduced (in 1926) to liquid form was helium. Now all substances which exist normally as gases can be reduced to liquid forms.
26. Imagination arises from sensation because persons who are congenitally blind do not have visual imagery.
27. A student found a considerable difference in the velocities of the same reaction between the same chemicals in two similar flasks, the one in an electrical field and the other not. He first regarded the variation as an electrical effect. Then he noticed that the metal in the coil influenced the temperature of the reaction mixture. When the temperature was kept constant, no change in reaction velocity occurred.
28. Since no branch of education in itself is strictly indispensable, we are compelled to conclude that we may dispense with education altogether.
29. It is just for women to participate in government, for government is only a kind of national housekeeping, and it is admitted that women are capable in housekeeping.
30. In political discussion one easily overlooks the mutuality of cause and effect. An energetic and restless nation, exposed to attack from neighbors, organizes military institutions. These institutions promote among the people of that nation a warlike spirit. This spirit again assists the further development of military organizations.
31. George Washington warned his contemporaries against entering into entangling alliances with foreign powers. If we are to follow the wise principle which he advised, we must keep out of the League of Nations.
32. Dr. do Amaral declares that the popular superstition that alcohol cures snake bites is based on ignorance of snakes. Many snakes that bite are not poisonous; the majority of poisonous bites are not fatal. The victim drowns his despair in drink. When, on growing sober, he finds himself still alive, the alcohol gets the credit.
33. "The provisional government will make a great mistake if it does not level Dublin castle to the ground. There is an evil spell upon it, and its spirit is quite as capable of destroying the Irish Free State as it was of destroying the union with England."

Chapter XII. Deduction

1. Explain the relation between induction and deduction; illustrate.
2. Analyze the categorical proposition into all its parts, and explain the meaning of each.
3. What is meant by the distribution of terms? What terms in propositions *A, E, I,* and *O* are undistributed?
4. Restate each of the following sentences in the logical form of a categorical proposition, name its symbol, and represent the relation between its terms by means of circles:
   a. Raw rubber is composed of carbon and hydrogen.
   b. Glass is not crystalline.
   c. Afflictions are often salutary.
   d. Uranium is the heaviest known element.
   e. Not many people are able to appreciate cubistic art.
   f. Only the wise man is happy.
   g. If a figure does not have equal diagonals, it is not a rectangle.
5. Convert the first four propositions in question 4 above.
6. Convert each of the following propositions:
   a. Pines are evergreens.
   b. No true Moslem eats pork.
   c. Some men are not good executives.
   d. Every common nitrate is soluble.
   e. Some useful things are also beautiful.
7. Give the obverse of the propositions in question 6.
8. Obvert the following propositions:
   a. All that happens is necessitated.
   b. No values exist which are not functions of human interest.
   c. Some Americans appreciate classical Chinese wisdom.
   d. Not all of Kant's writings lack fine literary quality.
9. By combinations of obversion and conversion, and by any other valid changes, derive as many different valid propositions as possible from the assertion: All matter is atomic.
10. State the contraries and the contradictories of the propositions in question 8.
11. If proposition *I* is false, what can you infer concerning the truth or falsity of *A, E,* and *O?*
12. Why must each term in a categorical syllogism occur twice?
13. Which of the following arguments are valid and which invalid? If any are invalid, name the fallacies.

MAP	MAP	PAM	MAP	MIP	MEP
SOM	SEM	SAM	MIS	SAM	MIS
SEP	SEP	SAP	SIP	SOP	SEP

14. Show how deductive reasoning is employed in using the spectroscope.
15. In what stages of science is disjunctive reasoning most important?
16. Criticize each of the following propositions; point out any fallacies you can:

a. Sin causes suffering and, therefore, suffering is the result of sin.
b. "There is no truth, since the world is perpetually changing."
c. How much are twice four and seven?
d. No emotions are simple mental states, since all emotions are compound.
e. Why are primitive races cruel?
f. What is the connection between the changing of the moon and the changes of the weather?

17. What kinds of deductive inferences are employed in proving a theorem in geometry?
18. State the following proposition in hypothetical, disjunctive, and conjunctive forms: Sodium floats on water.
19. Classify the fallacies discussed in this chapter.
20. Draw, if possible, at least one valid conclusion from each of the following sets of premises.

a. D is greater than B; C is less than D.
b. L is a species of D; T belongs to the genus L.
c. All A is B; all C is B.
d. If M is N, P is Q; we know that P is Q.
e. Topaz scratches quartz; feldspar is scratched by quartz.

Miscellaneous Examples of Deduction

In each of the following exercises determine (*a*) what kind of deductive inference is present, (*b*) its proper logical form, and (*c*) whether or not it is valid; if it is invalid, name the fallacy:

21. If religion can elevate the soul, it will survive persecution; since this religion has survived persecution, we may be sure that it will elevate the soul. (Coffey)
22. If the strike had been called off, the men would be back at work; but since the men are not back, we suppose that the strike has not been called off. (Bode)
23. I could then only be accused with justice of acting contrary to my law, if I maintained that Muraena purchased the vote, and was justified in doing so. But I maintained that he did not buy the vote; therefore, I do nothing contrary to the law. (Cicero)
24. Gold is fusible because it is a metal and metals are fusible.
25. Mammals have red blood; hence, a frog is a mammal, for it has red blood.
26. All amusements are interesting; no lessons are amusements; therefore, no lessons are interesting.
27. This fungus is not a meadow-mushroom because its gills are not pink, and all meadow-mushrooms have pink gills.
28. No assemblyman from New York County voted for this resolution. Mr. C voted for this resolution; therefore, Mr. C is not from New York County.
29. What is universally believed is true; the existence of God is not universally believed; therefore, it is not true.
30. All good citizens are ready to defend their country. All good citizens vote

regularly at election. Therefore, all who vote regularly at elections are ready to defend their country.

31. All mountains have originated either as a result of volcanic elevation or of the horizontal folding of the earth's surface. The Alps are not of volcanic origin, and, therefore, they must be the result of upheavals in the terrestrial crust.
32. The course of a comet is either an ellipse, a parabola, or a hyperbola. Since this comet returns, it cannot move in either a parabola or an hyperbola. It must travel in an ellipse.
33. Commanding children to do things is either needless (if they want to do them already) or self-defeating (for it rouses antagonism). No coercion of children, therefore, can be justified.
34. Since inertial mass and gravitational mass are one and the same thing, all forms of existence which possess inertial mass must also manifest character in a gravitational field. As all forms of energy possess inertial mass, we see that energy has weight.
35. If Congress is Democratic, the Republican president will veto a reduction of the tariff. If Congress is Republican, there will be no attempt to reduce the tariff. But Congress will be either Democratic or Republican. Therefore, there will be no reduction of the tariff.
36. An employer noticed that one of his employees was living apparently at a standard of about $5000 a year. Since he knew that his salary was $2000 and believed that he had no other source of income, he suspected that perhaps he was stealing money from the funds of the firm, to which he had access.
37. In any proportion, the product of the extremes is equal to the product of the means. If we are given the proportion, $a : b :: c : d$, and are to prove that $ad = bc$, we state our proportion as a fraction, thus: $a/b = c/d$, and multiply each member by bd. The result is $ad = bc$, for if equals are multiplied by equals, the products are equal.

    Now experimental esthetics has shown that the proportion of $5 : 8$ is the most generally pleasing proportion for a rectangular figure. If, then, I want a printed announcement card to be three inches wide, the length of the other side may be found by finding x in the following proportion: $5 : 8 :: 3 : x$. But we have proved above that $5x = 8 \times 3$. After dividing each side of the equation by 5, we find x to be 4.8 inches.

Chapter XIII. Verification

1. Is truth definable? Why?
2. Why is the problem of the nature of truth connected with the question of the aim of science?
3. Distinguish intrinsic from extrinsic correctness.
4. With which type of correctness is formal logic concerned?
5. What is a criterion?
6. How can a criterion for the truthfulness of a theory be reached?

7. What are the criteria for truth? Explain your reasons for agreeing or disagreeing with the position of the text.
8. Explain error. Why do you not believe that the world is flat? That the sun literally " rises " in the morning?
9. Explain the doctrine of the " will to believe " as James stated it.
10. What part do one's preferences play in the establishing of truth? Explain fully your position.

Chapter XIV. Discovery

1. Where may we look for information regarding conditions favorable to discovery?
2. How is it possible to lay down any rules at all that may help in discovery?
3. What kinds of knowledge are especially important for a discoverer to possess?
4. Explain: " Imitation is the schoolmaster of invention."
5. Find the key to one of the following cryptograms:

   (a) DCIUQHIQNFNKGVGPHGGVYGUVQHVJGDKIIGUVVTGGUQW
   VJUKFGQHNQQMQWVOQWPVCKP

   (b) PFISBORKABOYFDPQLKBXQIBCQBKQOXKZBQLZXSB

6. What are the dangers to be avoided in analogical reasoning?
7. Point out some ways in which comparison aids discovery.
8. With the following ingredients invent at least two original recipes: cauliflower, pork loin, onions, potatoes, bread, common seasonings.
9. Explain the function of hypotheses in scientific procedure. Why are they so important?
10. What are the distinctive features of postulational thinking?
11. Indicate as many ways as you can in which imagination may be cultivated.
12. Invent six different artistic ways of writing number 808.
13. What is meant by inspiration? What is its function, if any, in discovery?
14. Mention some ways of providing favorable mental conditions for discovery.
15. Indicate as many ways as you can in which society may promote discovery.
16. Why is coöperation in research so important at the present time?
17. Make as many suggestions as you can as to how to go about the selection of a research problem.

Chapter XV. Statistical Methods

1. Why are statistical methods important at the present time?
2. Criticize the following argument: A newspaper once stated that it is safer to serve as a sailor in Uncle Sam's navy in war time than to live in New York City in peace, because during the Spanish American War the death rate in the Navy was nine per thousand while in New York City during the same period it was sixteen.

3. How is it possible for gamblers to run for a long time with small odds in their favor?
4. What is the basic axiom or postulate of statistical methods?
5. Explain exactly under what circumstances the scientist makes use of statistical rather than other methods.
6. Point out the kinds of mistakes that might be made in taking a census.
7. Mention the chief virtues and the chief faults in statistical observation.
8. What are the important rules for obtaining fair samples?
9. Describe the structure of two common graphs.
10. Define average, and describe several kinds of averages.
11. What kind of average would be best to determine: the average weight of a football team, the daily temperature, the sizes of shoes for a store, the opinions of the members of a community?
12. Explain one special advantage which each kind of average may sometimes have.
13. What statistical methods are involved in determining how late in the fall it is safe to leave perishable vegetables in the field?
14. How may the reliability or degree of accuracy possessed by an average be determined?
15. Explain exactly what is meant by correlation.
16. The following figures are taken from the 1921–1922 reports in logic in Syracuse University; for simplification, 25 students older than 22 are omitted:

Age	*Number of Students*	*Grade*
17	8	81
18	21	79
19	51	78
20	29	75
21	20	76
22	6	70

Determine the following facts; carry decimals out one place:

a. Plot the data so as to correlate age (horizontal axis) and number of students (vertical axis).

b. Arithmetical average of the grades.

c. Weighted average of the ages (age 17 means 16.6 to 17.5 inclusive).

d. What age is the mode?

e. What age is the median?

f. Compute the weighted average deviation of grades from their arithmetical mean.

g. State, if possible, a rough, non-mathematical correlation between ages and grades.

17. What is probability, and how calculate it according to Laplace's formula?
18. Explain the rule for calculating probabilities of independent events.
19. At an evening party 30% of the persons present are freshmen, and 70% of

the freshmen are from New York State. What is the probability that the next person one might meet would be a freshman from outside of New York State?

20. How would you proceed scientifically to purchase a farm west of the Mississippi River for raising a certain crop?
21. If you were manager of a company operating a chain of stores in a large city, how would you proceed to determine the best place to locate a new store?

Chapter XVI. The Organization of Knowledge

1. Describe and illustrate the difference between a system and a collection.
2. Explain and illustrate each of the three general types of system mentioned.
3. Mention five different ways in which animals might be classified.
4. Arrange the following terms in the form of a logical tree; that is, write each term except the first or topmost one under another term of greater extension: animals, bipeds, bulldogs, Catholics, dogs, the earth, reality, greyhounds, heavenly bodies, human persons, inanimate matter, living matter, Methodists, non-Catholics, North Star, planets, plants, Presbyterians, quadrupeds, roses, Saturn, Wesleyan Methodists, stars.
5. Criticize the following divisions:
   a. Soldiers into artillery, cavalry, privates, and volunteers.
   b. Religions into monotheistic and polytheistic.
   c. Fine arts into sculpture, painting, drawing, architecture, and photography.
6. What is the relation of explanation to inference and to system?
7. Give an example of each kind of explanation mentioned in the text. Name one science in which each kind of explanation is important.
8. What are the characteristics of teleological explanation?
9. Explain and illustrate the fallacies of explanation.
10. What are the chief difficulties and values involved in classifying the sciences?
11. Criticize Comte's classification of the sciences in as many ways as you can.
12. Fix in mind the main divisions of that classification of the sciences, other than Comte's, which you prefer.
13. What are the logical steps by which Münsterberg built up his classification of the sciences?
14. Try to improve upon the order of main topics in Dewey's classification. Evaluate classes 200 and 500. How does class 800 differ from the rest?
15. Work out the main divisions of a table for taking an inventory of household goods for the purposes of collecting fire insurance.
16. Contrast primitive knowledge with a highly developed science. How does knowledge grow?
17. Write out a table of commandments for scientific thinking.

PART III. OTHER PHILOSOPHICAL DISCIPLINES

Chapter XVII. Ethics

1. Mention as many sources as you can for the data of ethics.
2. Point out the defects of a customary morality.
3. Indicate the several steps in a moral act at the reflective stage of conduct.
4. Illustrate the three meanings of *good.*
5. Contrast *means* and *ends.*
6. What regulates the conduct of men before they become reflective moralists?
7. Contrast *good* and *right.*
8. What is a moral law? Why is it called *moral,* and why *law?*
9. Of what use are ethical standards?
10. What is *conscience?*
11. Define and illustrate *self* as an ethical notion.
12. Point out the advantages of reflective over instinctive behavior.

Chapter XVIII. Esthetics

1. Point out as many similarities and contrasts as you can between the useful and the fine arts.
2. Compare the scientific and esthetic attitudes.
3. What are the chief characteristics of a work of art?
4. Explain the advantages and disadvantages, for the purposes of the fine arts, of one of the senses other than eye and ear.
5. Give reasons for and against putting photography in the list of the fine arts.
6. Explain what is meant by criticism in general; by technical criticism.
7. Explain and demonstrate the value of the historical criticism of art. Give two examples of historical generalizations.
8. Give some examples of social influences in the origin and creation of art.
9. Give some examples to show how physiological processes influence art.
10. Illustrate and criticize the use of experiment in esthetics.
11. What are the main problems of a philosophy of art?
12. Point out one advantage of each of the following arts over any other: music, poetry, painting, sculpture.
13. Point out as many characteristics as you can of contemporary expressionism.
14. Point out as many characteristics, faults, and virtues as you can in Figure 26.
15. Explain the meaning of, and reasons for, unity in variety. Indicate some of its chief types.
16. What is meant by style, symmetry, balance, rhythm, and contrast?
17. What are the chief obstacles to achieving the experience of the beautiful?
18. What is meant by beauty?
19. Show how each of Volkelt's norms is realized in Figure 27 or Figure 28.
20. Discuss the following questions concerning Raphael's *Sistine Madonna* (Figure 28):

a. What geometrical form is dominant? Does it recur anywhere in the picture?
b. Criticize the filling of space, the arrangement of figures, and the lines used.
c. Point out as many signs as you can which indicate where the scene is enacted.
d. What indications of spatial depth are present? of movement?
e. Point out any examples of balance, contrast, and rhythm you can find.
f. What is the dominant emotion expressed in the picture? In what ways is it suggested?
g. Point out anything in the picture which is inharmonious, needless, or erratic. Could the cherubs be omitted?
h. Mention any other reasons why you like or dislike the picture.

Chapter XIX. The Study of Religion

1. Why are vague ideas of religion common?
2. What are the values and dangers of religious creeds?
3. What is the place or function of emotion in religion?
4. What are the dangers and the values of the practical view of religion? Must religion have a moral aspect?
5. What are the main factors which need to be included in an adequate definition of religion?
6. What is the purpose and what are the main problems of the psychology of religion?
7. Distinguish three phases of conversion and point out the characteristics of each.
8. Illustrate the influence of social life upon theological conceptions.
9. Explain and illustrate the comparative method in religion.
10. How does the philosophical approach to religion differ from other approaches?
11. What are the chief elements in your conception of God?
12. What is the purpose of theology?
13. What influences tend to undermine a religion based on authority?
14. What can be said in favor of the traditionalist's attitude to religion?
15. What can you say for and against a scientific study of religion?

Chapter XX. Metaphysics

1. What are some of the sources from which the man in the street derives his philosophy of life?
2. How would you distinguish real objects from imaginary ones and from illusory ones?
3. Explain and criticize naturalism.
4. Explain and criticize the point of view of idealism.

5. What are the most fundamental characteristics of the human self?
6. Why is the historical approach to philosophy important?
7. Explain what is meant by reason.
8. Explain just what is meant by regressive criticism.
9. Explain the philosophical ideal expressed in the synthetic method.
10. Explain what is meant by interpretation.
11. Why is frequent revision necessary in philosophy?
12. Point out as many differences as you can between the points of view of science and philosophy.
13. What are the chief characteristics of the philosophic attitude?

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(By Otto v St. Whitelock)